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CARNEGIE INSTITUTION
OF
WASHINGTON

YEAR BOOK No. 34

JULY 1, 1934 -JUNE 30, 1935

WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 13, 1935



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WASHINGTON, 1935

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PRESIDENT AND TRUSTEES

PRESIDENT

JOHN C. MERRIAM

BOARD OF TRUSTEES

ELIHU ROOT, *Chairman*

W. CAMERON FORBES, *Vice-Chairman*

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FREDERIC A. DELANO	ANDREW W. MELLON	JAMES W. WADSWORTH
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WALTER S. GIFFORD	STEWART PATON	LEWIS H. WEED
	ELIHU ROOT	

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FREDERIC C. WALCOTT GEORGE W. WICKERSHAM

Auditing Committee: FREDERIC A. DELANO, *Chairman*

HOMER L. FERGUSON WILLIAM BENSON STOREY

FORMER PRESIDENTS AND TRUSTEES

PRESIDENTS

DANIEL COIT GILMAN, 1902-04

ROBERT SIMPSON WOODWARD, 1904-20

TRUSTEES

ALEXANDER AGASSIZ	1904-05	HENRY CABOT LODGE	1914-24
GEORGE J. BALDWIN	1925-27	SETH LOW	1902-16
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CLEVELAND H. DODGE	1903-23	WILLIAM CHURCH OSBORN	1927-34
WILLIAM E. DODGE	1902-03	JAMES PARMELEE	1917-31
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CASS GILBERT	1924-34	THEOBOLD SMITH	1914-34
FREDERICK H. GILLET	1924-35	JOHN C. SPOONER	1902-07
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JOHN HAY	1902-05	WILLIAM S. THAYER	1929-32
MYRON T. HERRICK	1915-29	CHARLES D. WALCOTT	1902-27
ABRAM S. HEWITT	1902-03	HENRY P. WALCOTT	1910-24
HENRY L. HIGGINSON	1902-19	WILLIAM H. WELCH	1906-34
ETHAN A. HITCHCOCK	1902-09	ANDREW D. WHITE	1902-16
HENRY HITCHCOCK	1902-02	EDWARD D. WHITE	1902-03
WILLIAM WIRT HOWE	1903-09	HENRY WHITE	1913-27
CHARLES L. HUTCHINSON	1902-04	ROBERT S. WOODWARD	1905-24
SAMUEL P. LANGLEY	1904-06	CARROLL D. WRIGHT	1902-08
WILLIAM LINDSAY	1902-09		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR THE YEAR 1935

Physical Sciences

Geophysical Laboratory

Organized 1906, opened 1907.

ARTHUR L. DAY, Director
I. H. ADAMS
TOM. F. W. BARTH
N. L. BOWEN
C. N. FENNIR
R. E. GIBSON
R. W. GORANSON
J. W. GREIG
J. H. HIBBEN
EARL INGERSOLL
F. C. KRACEK

C. J. KSANDA
H. E. MERWIN
G. W. MOREY
CHARLES S. PIGGOT
EUGENE POSNJAK
H. S. ROBERTS
J. F. SCHLAIRER
E. S. SHEPHERD
GEORGE TUNELL
FRED F. WRIGHT
E. G. ZIES

Seismological Research

Advisory Committee in Seismology, Arthur L. Day, Chairman.

H. O. WOOD, Research Associate
HUGO BENIOFF
WILLIAM W. MILLER

CHARLES F. RICHTER
R. K. ROGERS

Mount Wilson Observatory

Organized 1904; George E. Hale, Director 1904-1923.

GEORGE E. HALE, Honorary Director
WALTER S. ADAMS, Director
F. H. SEARES, Assistant Director
ALFRED H. JOY, Secretary
A. S. KING, Supt. Physical Laboratory
J. A. ANDERSON
WALTER BAADÉ
HAROLD D. BAIXOCK
THEODORE DUNHAM JR.
FERDINAND KLEMMER
EDWIN P. HUBBLE

MILTON L. HUMASON
PAUL W. MERRILL
SETH B. NICHOLSON
FRANCIS G. PEASE
EDISON PETTIT
R. S. RICHARDSON
R. F. SANFORD
SINCLAIR SMITH
GUSTAF STROMBERG
A. VAN MAANEN

Department of Terrestrial Magnetism

Organized 1904; L. A. Bauer, Director 1904-1929.

J. A. FLEMING, Director
O. H. CHASE, Assistant Director
L. V. BERKNER
O. DAHL
F. T. DAVIES
C. R. DUVAL
C. C. ENNIS
S. E. FORBUSH
JOHN W. GREEN
L. R. HANSTAD
C. HUFF
H. F. JOHNSTON

P. G. LEDIG
A. G. MCNISH
WILFRED C. PARKINSON
W. J. ROONEY
W. E. SCOTT
K. L. SHERMAN
OSCAR W. TORRESON
M. A. TUTT
G. R. WAIT
W. F. WALLIS
H. W. WELLS

Department of Meridian Astrometry

Organized 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director
HEROY JENKINS
HARRY RAYMOND

ARTHUR J. ROY
W. B. VARNUM
RALPH E. WILSON

Division of Plant Biology: H. A. SPOEHR, Chairman

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology, in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

Photosynthesis

H. A. SPOEHR
JAMES H. C. SMITH
H. H. STRAIN
H. W. MILNER

Experimental Taxonomy

JENS C. CLAUSEN
DAVID D. KECK

Ecology

FREDERIC E. CLEMENTS
FRANCES L. LONG

Desert Laboratory

FORREST SHREVE
T. D. MALLERY

Division of Animal Biology: GEORGE L. STREETER, Chairman

An administrative grouping made effective in 1935, including activities of the following Departments.

Department of Embryology

Organized 1914; Franklin P. Mall, Director, 1914-1917.

GEORGE L. STREETER, Director
CARL G. HARTMAN
CHESTER H. HEUSER

MARGARET R. LEWIS
WARREN H. LEWIS
CHARLES W. METZ

Department of Genetics

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934.

A. F. BLAKESLEE, Acting Director
H. H. LAUGHLIN, Assistant Director
A. G. AVERY
R. W. BATES
A. DOROTHY BERGNER

M. DEMEREC
E. C. MACDOWELL
OSCAR RIDDLE
SOPHIA SATINA
MORRIS STEGGERDA

Nutrition Laboratory

Organized in 1907, opened in 1908.

FRANCIS G. BENEDICT, Director
T. M. CARPENTER

V. COROPATCHINSKY
ROBERT C. LEE

Tortugas Laboratory

Established in 1904. Alfred G. Mayor, Director 1904-1922. Open for marine biological studies during summer months.

W. H. LONGLEY, Executive Officer

Division of Historical Research: A. V. KIDDER, Chairman

Department of Historical Research was organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

Section of Aboriginal American History

SYLVANUS G. MORLEY
EARL H. MORRIS
H. E. D. POLLOCK
O. G. RICKETSON JR.
H. B. ROBERTS
KARL RUPPERT
A. LEONARD SMITH
J. ERIC THOMPSON

Section of United States History

CHARLES O. PAULLIN
RALPH L. ROYS
FRANCE SCHOLES
LEO F. STOCK

Section of the History of Science

GEORGE SARTON
ALEXANDER POGO
MARY WELBORN

Associated Investigators

W. A. HEDEL
ELIAS A. LOWE

Research Associates

SOPHIE D. ABERLE, Anthropology
SEBASTIAN ALBRECHT, Astronomy
PAUL S. CONGER, Biology
A. E. DOUGLASS, Climatology
W. S. CLOCK, Climatology

C. B. BRIDGES, Biology
JACK SCHULTZ, Biology
WALDEMAR JOCHELSON, Archaeology
F. A. PERRET, Geophysics

Research Associates Engaged in Post-retirement Studies

EDMUND C. BURNETT, History
CHARLES B. DAVENPORT, Biology
D. T. MACDOUGAL, Botany
W. J. PETERM, Terrestrial Magnetism

GODFREY SYKES, Physiography
WALTER P. WHITE, Geophysics
GEORGE R. WIELAND, Palaeobotany

Research Associates Connected with Other Institutions

ERNEST ANDERSON (University of Arizona), Plant Biology
M. J. ANDRADE (University of Chicago), Linguistics
ERNEST ANTEVS (University of Stockholm), Palaeontology
E. B. BABCOCK (University of California), Genetics
I. W. BAILEY (Bussey Institute), Plant Biology
J. BARTHEL (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism
V. BJERKNES (University of Oslo, Norway), Meteorology
G. BREIT (University of Wisconsin), Physics
J. P. BUWALDA (California Institute of Technology), Palaeontology
IAN CAMPBELL (California Institute of Technology), Geology
W. E. CASTLE (Harvard University), Biology
RALPH W. CHANEY (University of California), Palaeobotany
S. CHAPMAN (Imperial College, London), Terrestrial Magnetism
A. H. COMPTON (University of Chicago), Physics
K. T. COMPTON (Massachusetts Institute of Technology), Physics

H. E. CRAMPTON (Columbia University), Biology
 H. DE TERRA (Yale University), Palæontology
 L. R. DICE (University of Michigan), Biology
 M. R. HARRINGTON (Southwest Museum), Archæology
 NORMAN E. A. HINDS (University of California), Geology
 EDGAR B. HOWARD (University of Pennsylvania), Palæontology
 J. H. JEANS (Royal Society of London), Astronomy
 THOMAS H. JOHNSON (Bartol Research Foundation), Physics
 REMINGTON KELLOGG (U. S. National Museum), Palæontology
 A. E. KENNELLY (Harvard University), Terrestrial Magnetism
 P. A. LEIGHTON (Stanford University), Chemistry
 W. H. LONGLEY (Goucher College), Biology
 JOHN H. MAXSON (California Institute of Technology), Geology
 L. B. MENDEL (Yale University), Physiological Chemistry
 R. A. MILLIKAN (California Institute of Technology), Physics
 RUDOLF MINKOWSKI, Astronomy
 S. A. MITCHELL (University of Virginia), Astronomy
 T. H. MORGAN (California Institute of Technology), Biology
 FRANK MORLEY (Johns Hopkins University), Mathematics
 ROBERT REDFIELD (University of Chicago), Anthropology
 I. I. RABI (Columbia University), Chemistry
 E. G. RITZMAN (New Hampshire Agric. Exper. Station), Nutrition
 HENRY A. RUGER (Columbia University), Psychology
 G. OSCAR RUSSELL (Ohio State University), Physiology
 HENRY N. RUSSELL (Princeton University), Astronomy
 H. C. SHERMAN (Columbia University), Nutrition
 JOEL STEBBINS (University of Wisconsin), Astronomy
 CHESTER STOCK (California Institute of Technology), Palæontology
 H. U. SVERDRUP (Geofysisk Institute, Bergen, Norway), Terrestrial Magnetism
 HAROLD C. UREY (Columbia University), Chemistry
 H. B. VICKERY (Connecticut Agric. Exper. Station), Physiological Chemistry
 LEWIS H. WEED (Johns Hopkins University), Anatomy
 BAILEY WILLIS (Stanford University), Seismology

OFFICES OF ADMINISTRATION

JOHN C. MERRIAM, President

President's Office

JOHN C. MERRIAM, President
 WALTER M. GILBERT, Administrative Secretary
 SAMUEL CALLAWAY, President's Secretary

Office of Publications

FRANK F. BUNKER, Editor
 IRVING M. GREY, Secretary

Bursar's Office

EDMUND A. VARELA, Bursar
 EARLE B. BIESECKER, Assistant Bursar

ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the endowment fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION

PUBLIC No 260—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh,

ARTICLES OF INCORPORATION

Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by

ARTICLES OF INCORPORATION

mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property, hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secre-

BY-LAWS OF THE INSTITUTION

tary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

BY-LAWS OF THE INSTITUTION

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE THIRTY-SIXTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 13, 1935. It was called to order at 10 a.m. by the Secretary of the Board, Mr. Delano. Upon motion, Mr. Forbes served as temporary Chairman of the meeting.

Upon roll-call, the following Trustees responded: Thomas Barbour, W. W. Campbell, Frederic A. Delano, W. Cameron Forbes, Walter S. Gifford, Frank B. Jewett, Charles A. Lindbergh, Alfred L. Loomis, Roswell Miller, Stewart Paton, John J. Pershing, Richard P. Strong, James W. Wadsworth, Frederic C. Walcott, and George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the thirty-fifth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1936 were authorized:

Pension Fund	\$ 60,000
Administration	67,900
Publications (including Division of Publications) ...	97,520
Departments and Divisions of Research.....	1,112,080
Minor Grants	109,500
General Contingent Fund.....	50,000
Special Emergency Reserve Fund.....	75,000

1,572,000

Balloting for new Trustees to fill two vacancies, one having carried over from the last meeting of the Board and the other being occasioned by the death of Frederick H. Gillett, resulted in election of James F. Bell, of Minneapolis, and Lewis H. Weed, of Baltimore.

The resignations of Henry S. Pritchett as Vice-Chairman of the Board, as Chairman of the Executive Committee and as Chairman of the Finance Committee were accepted with regret. W. Cameron Forbes was elected Vice-Chairman of the Board and Chairman of the Executive Committee, and Alfred L. Loomis was elected Chairman of the Finance Committee.

Walter S. Gifford and Frederic C. Walcott were elected to succeed themselves for a period of three years as members of the Executive Committee. Lewis H. Weed was elected a member of the Executive Committee to fill the unexpired term of Mr. Pritchett, and Frederic C. Walcott was elected a member of the Finance Committee to fill the unexpired term of Mr. Pritchett.

REPORT OF THE EXECUTIVE COMMITTEE

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1935.

During this year the Executive Committee held six meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 14, 1934, the members of the Executive Committee met and organized by the election of Mr. Pritchett as Chairman for 1935.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith. Continuing attention has been given both by the Executive Committee and the Finance Committee to the question of income under present economic conditions. Budget recommendations for next year are based upon opinion of these Committees with respect to financial policy concerning protection both of capital and of income against possible losses.

The Board of Trustees, at its meeting of December 14, 1934, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1935. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1935, is submitted as a part of the report of the Executive Committee.

There is also submitted a financial statement for the fiscal year ending October 31, 1935, showing funds available for expenditure and amounts allotted by the Executive Committee. A customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, is included.

Two vacancies exist in membership of the Board of Trustees, one having been left unfilled at the last annual meeting of the Board of Trustees and the other having been caused by death of Frederick H. Gillett on July 31, 1935. Nominations to fill these vacancies have been requested, received and

CARNEGIE INSTITUTION OF WASHINGTON

distributed in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 13, 1935.

Tenures of office of the following members of the Executive Committee will expire at the annual meeting on December 13: Walter S. Gifford and Frederic C. Walcott.

HENRY S. PRITCHETT, *Chairman*
 FREDERIC A. DELANO
 W. CAMERON FORBES
 WALTER S. GIFFORD
 JOHN C. MERRIAM
 STEWART PATON
 ELIHU ROOT
 FREDERIC C. WALCOTT

November 20, 1935.

Financial Statement for Fiscal Year Ending October 31, 1935

	Balances unallotted Oct. 31, 1934	Trustees' appropri- ation Dec. 14, 1934	Rever- ments and transfers Nov. 1, 1934, to Oct. 31, 1935	Total available 1935	Executive Committee allotments 1935	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1935
Large Grants:							
Animal Biology:							
Administrative Expenses		\$1,500		\$1,500	\$1,500		
Embryology		73,863	\$1,000	75,463	75,463		
Genetics		129,395	6,346	135,740	135,740		
Nutrition Laboratory		45,220	2,000	47,220	47,220		
Tortugas Laboratory		14,000	300	14,300	14,300		
Geophysical Laboratory		163,522	240	163,762	163,762		
Historical Research		155,850	4,192.56	160,042.56	160,042.56		
Meridian Astrometry		16,920	8,740	25,700	25,700		
Mount Wilson Observatory		218,430	4,450	222,880	222,880		
Plant Biology		98,310	15,100	113,410	113,410		
Terrestrial Magnetism		181,840	5,180	187,020	187,020		
Minor Grants	\$87.16	121,300	30,550	151,937.16	151,642		\$295.16
Publications	55,297.90	101,320	7,157.11	163,775.01	111,363.55		52,411.46
Administration		87,900	4,690	72,590	72,590		
Pension Fund		80,000		80,000	80,000		
General Contingent Fund	53,911.60	76,000	35,035.29	164,946.89	29,138.09	\$81,867.56	53,941.24
Special Emergency Reserve Fund		50,000		50,000	50,000		
	109,296.66	1,575,370	125,659.96	1,810,326.62	1,621,811.20	81,867.56	106,647.86

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1935

RECEIPTS	DISBURSEMENTS
<i>Interest from— Securities and Bank Balances.....</i>	<i>Investment.....</i> (*) \$55,096,047.85
<i>Colburn Fund.....</i>	<i>Pension Fund.....</i> 725,195.71
<i>Sales of Publications.....</i>	<i>Insurance Fund.....</i> 101,793.60
<i>Reversions.....</i>	<i>General Contingent Fund.....</i> 104,866.54
<i>Pension Fund.....</i>	<i>Special Emergency Reserve Fund.....</i> 121,212.56
<i>Insurance Fund.....</i>	<i>Special Reserve Fund for Administration Bldg. Additions.....</i> 1,828.79
<i>Special Reserve Fund for Administration Building Additions (Rentals).....</i>	<i>Grants</i> <i>Large.....</i> \$26,644,063.76 <i>Minor.....</i> 4,694,344.15
<i>Redemption and Sale of Bonds.....</i>	<i>Publication.....</i> 2,263,396.46
<i>Carnegie Corporation of New York.....</i>	<i>National Research Council.....</i> 150,000.00
<i>Miscellaneous.....</i>	<i>Administration.....</i> 1,887,181.26
	<i>Cash in Banks.....</i> 91,789,930.68

(*) Including Administration Building, \$309,915.69, and Collection Charges.

REPORT OF AUDITORS

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1935.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were either verified by inspection or by certificates obtained from custodians and depositories. The detail accounts of the Departments of Research in the field as in past years have been audited by the Bursar of the Institution and we are of opinion as a result of reviewing the internal audit methods in force that such internal audit is satisfactorily conducted.

The securities are stated at cost or value at date acquired, this being the established custom of the Institution. Real estate and equipment are stated at original cost and books on hand for sale at their sales prices.

We inspected certified copies of the minutes of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion on the basis of valuation above stated, the accompanying Balance Sheet, detailed schedule of securities and statement of receipts and disbursements properly present the financial position of the CARNEGIE INSTITUTION OF WASHINGTON at October 31, 1935, and its transactions for the year ended that date.

ARTHUR YOUNG & COMPANY,
Accountants and Auditors.

New York, N. Y., November 25, 1935.

Balance Sheet, October 31, 1935

Assets		Liabilities	
<i>Investments</i>		<i>Endowment and Other Funds</i>	
Securities.....	\$34,496,943.93	Endowment.....	\$29,832,616.26
Cash.....	463,003.09	Colburn Fund.....	111,485.08
Awaiting investment.....	35,940.31	Reserve Fund.....	3,160,478.20
Reserved for current needs.....		Insurance Fund.....	598,294.58
		Pension Fund.....	322,166.83
		Harriman Fund (\$183,-	
		671.76 included in Prop-	
		erty Fund below).....	299,037.47
		Special Emergency Reserve	
		Fund.....	342,034.30
		Special Reserve Fund for	
		Administration Building	
		Addition.....	45,608.50
		Unappropriated Funds In-	
		vested.....	45,000.00
			34,786,721.22
		Increase from redemption	
		and sale of securities	
		(awaiting yearly appor-	
		tionment).....	199,166.16
			\$34,985,887.38
<i>General Fund</i>		<i>Property Fund</i>	
Cash.....	\$351,043.15	Income Invested.....	3,800,906.23
Income account.....	500.00	Harriman Property (Gift)..	153,671.75
Petty cash and stamps.....			3,954,577.98
		<i>General Fund</i>	
		Current Obligations	
		Large Grants.....	\$251,251.49
		Minor Grants.....	56,298.78
		Publications.....	123,432.48
		Administration.....	23,124.65
		General Contingent Fund	
		65,206.47	522,313.80
		Unappropriated Fund.....	49,817.83
		Less Funds Invested	
		(See above).....	45,000.00
			4,817.83
		Value of Publications and	
		Invoices.....	267,193.13
		Publication Paper Stock.....	6,792.97
			\$61,117.73
			39,771,583.09

Receipts and Disbursements for Year Ending October 31, 1935

RECEIPTS		DISBURSEMENTS	
<i>Interest from Securities</i>	\$1,644,639.21	<i>Investment Securities</i>	\$3,531,508.59
<i>Sales of Publications</i>		<i>Accrued Interest</i>	44,492.28
Index Medicus.....	\$29.60	<i>Pension Fund</i>	66,320.16
Year Book.....	73.28	<i>Insurance Fund</i>	5,209.93
Miscellaneous Books.....	4,113.52	<i>General Contingent Fund</i>	28,878.35
<i>Reversions</i>		<i>Special Emergency Reserve Fund</i>	31.49
Large Grants		<i>Special Reserve Fund for Administration Building Additions</i>	230.09
Departments	34,444.74	<i>Grants</i>	
Contributions		Large.....	1,192,505.99
National Research Council	1,600.00	Minor.....	188,877.46
California Institute Technology	12,599.58	<i>Publication</i>	
International Cancer Research Foundation	1,700.02	General Publication.....	43,995.40
Rockefeller Foundation.....	1,000.00	Catalogues, etc.....	1,172.83
		Shipping Expenses.....	5,905.15
		Division of Publications.....	26,636.67
	51,344.64	<i>Administration</i>	
Minor Grants.....	4,760.51	Trustees.....	2,461.81
Publication.....	1,601.52	Executive Committee.....	2,845.59
Administration.....	2,254.72	Salaries.....	46,200.00
Unappropriated Fund.....	521.30	Surety, postage, tel. & tel.....	2,066.21
General Contingent Fund.....	63.53	Printing, paper.....	1,591.50
		Office expenses.....	4,674.74
		Equipment.....	416.25
		Building, maintenance.....	4,938.32
		Lectures and Exhibits.....	3,663.27
		Contingent.....	112.50
<i>Pension Fund</i>	60,546.22		68,970.19
<i>Insurance Fund</i>	4,063.56	<i>Cash in Banks</i>	
<i>Special Reserve Fund for Administration Building Additions (Rentals)</i>	379.81	Uninvested Principal.....	5,502,734.58
<i>Redemption and Sale of Securities</i>	2,302.59	Awaiting Investment.....	463,003.09
<i>Carnegie Corporation of New York</i>	4,105,497.04	Reserved for current needs.....	35,940.31
	80,050.00		
		<i>Income Account</i>	498,943.40
	5,961,599.83		882,991.55
<i>Balance in Banks, Oct. 31, 1934</i>	424,126.30		
			6,385,726.13
	6,385,726.13		

Schedule of Securities

Aggregate— Par or Nominal Value	Description	Registered		Maturity	Int. Due	Total Cost or Value at Date Acquired
		Price Int.	Price Only			
Railroads						
\$500,000	A. T. & S. Fo. 1st & ref. 4½s.			1962	M N	\$498,750.
43,000	conv. 4s.			1955	J D	39,022.50
50,000	A. T. and S. Fe. gen. 4s.			1965	A O	50,036.25
50,000	Balto. & Ohio R. R. ref. 4s.			1911	M N	46,840.
100,000	B. & O. R. R. 1st Mtg. 5s.			1918	J A D O	105,500.
100,000	B. and O. R. R. gen. and ref. 5s.			1965	J D	102,410.07
50,000	Boston & Maine 1st 3s.			1900	M N	30,307.50
200,000	Canadian National Ry. Co. 5s.			1967	M N	195,812.50
100,000	Canadian Pac. Col. Trust 5s.			1969	J J	98,000.
100,000	Canada So. con. 5s.			1936	F A	98,000.
30,000	Ches. & Ohio Ry. gen. 4½s.			1962	A O	153,710.07
175,000	Ches. and Ohio Ry. ref. and imp. 4½s.			1962	M N	174,062.50
60,000	Series A.					
115,000	Ches. and Ohio Ry. ref. and imp. 4½s.			1903	A-O	54,100.
	Series B.					
100,000	Ches. & O. Ry. Eq. Tr. 4½s.			1905	J-J	111,150.
50,000	Cent. Pac. Ry. 1st ref. 4s.			1931 10	M N	96,825.50
180,000	Chicago B. & Q. R. R. gen. 4s.			1917	F A	48,250.
200,000	Chicago B. and Q. Ill. Div. 4s.			1958	M N	199,000.
35,000	Chicago M. St. P. & P. 5s.			1919	J J	200,000.
189,000	Chicago, Ind. & L. 1st & gen. 5s.			1975	F A	31,833.50
140,000	Chicago M. St. P. & P. conv. adj. 5s.			1906	M N	189,461.25
234,000	Chicago M. and St. P. Ry. gen. 4½s.			2000	A O	127,111.50
	(\$5,000 fully registered).					
120,000	Chicago and N. W. Ry. gen. 3½s.			1980	J J	227,162.50
200,000	Chicago and N. W. Ry. gen. 4½s.			1987	FMAN	100,300.
300,000	Chicago, R. I. & P. Ry. 4½s.			1932	M N	210,000.
50,000	Chicago U. Station 1st 4½s.			1903	J-J	53,964.75
100,000	Chicago & W. Indiana R. Co. con. 4s.			1952	J J	97,122.50
50,000	Clev. C. C. & St. Louis, Ry. 1st 4s.			1939	J J	45,500.
100,000	Clev. C. C. & St. L. Ry. ref. and imp. 4½s.			1977	J J	99,272.50
100,000	Clev. C. C. & St. L. Ry. gen. 4s.			1903	J-J	78,906.25
50,000	Clev. U. Term. 1st sink. 5½s.			1972	A-O	51,612.50
125,000	Elgin J. & E. Ry. Eq. 5s.			1928	J J	125,000.
120,000	Erle R. R. 4s.			1930	A-O	120,000.
300,000	Erle R. R. gen. 4s.			1906	J-J	212,937.50
90,000	Erle R. R. Eq. Trust 4½s.			1912-13	J-J	80,167.00
69,000	Et. Nor. 1st ref. 4½s.			1901	J J	69,053.25
117,000	Et. Nor. gen. 4½s.			1977	J-J	114,800.25
173,000	Ill. Cent. R. R. 2s.			1973	J-J	180,547.50
300,000	Ill. Cent. R. R. Joint 5s.			1963	J-J	311,291.50
131,000	Ill. Cent. R. R. ref. 4s.			1957	M N	108,077.50
120,000	Ill. Cent. Eq., Trust, 4½s.			1942-14	A-O	108,077.50
200,000	Kan. City Term. 1st 4s.			1980	J-J	179,728.76
200,000	Kan. City, F. & M. Ry. ref. 4s.			1936	A-O	187,250.
305,000	Lehigh & N. E. 4½s.			1957	M N	311,161.10
100,000	Lehigh & N. Term. Ry. 1st 3s.			1951	F A	107,000.
50,000	Long Island ref. 4s.			1910	M N	48,245.
250,000	Louisville & N. R. R. 1st & ref. 4½s.			2003	A-O	349,125.
100,000	Mo. Kan. & T. 1st 4s.			1960	J J	82,003.13
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s.			1977	M N	212,762.50
200,000	Mo. Pac. R. R., Eq. Trust 4½s.			1939 42	M N	192,206.70
150,000	Mobile and O. R. R. ref. and imp. 4½s.					
	(Certificate of Deposit).					
55,000	Morris & Essex R. R. Co., Construction Mtg. 4½s.			1977	M-N	545,750.
175,000	N. Y. Cent. R. R. ref. & imp. 5s.			1955	M N	162,937.50
50,000	New York, Penna. & Ohio R. R. 4½s.			2013	A O	186,000.25
50,000	N. Y. W. and Boston 1st 4½s.			1950	M-N	52,500.
150,000	Nor. Pac. ref. and imp. 5s.			1916	J J	46,187.84
50,000	Ore. Short Line con. 5s.			2017	J J	150,150.
51,000	Ore. Wash. & N. 1st ref. 4s.			2017	FMAN	33,101.25
310,000	Pa. R. R. Co. gen. 4½s.			1940	J-J	49,883.25
80,000	Pa. R. R. con. 4½s.			1961	J J	274,272.50
125,000	Penna. R. R. Co. gen. Mtg. 5s.			1963	J-J	80,000.
100,000	Penna. R. R. Co. gen. Mtg. 5s.			1960	F-A	130,703.13
50,000	Pere Marquette Ry. Co. 1st Mtg. 5s.			1908	J-J	113,375.
200,000	Pitts. C. & St. L. 5s (\$100,000 registered as to principal).			1936	J-J	44,282.60
42,000	Pitts. Shawmut & Nor. 4s (Certificate of Deposit).			1973	A-O	211,987.50
125,000	So. Pac. 1st ref. 4s (\$100,000 fully reg.)			1952		4,200.
200,000	So. Pac. 4½s.			1955	J-J	116,617.50
350,000	So. Rwy. Co. 1st con. 5s (\$100,000 reg. as to principal).			1969	M-N	180,000.
45,000	St. Paul Union D. 1st & ref. 5s.			1961	J-J	362,331.25
225,000	St. Louis & F. prior lien 4s.			1972	J-J	49,150.
32,000	Term. R. R. Ass'n 1st Mtg. 4½s.			1950	J-J	203,431.25
230,000	Term. R. R. Assn. 4s (\$12,000 reg. as to principal).			1969	A-O	30,400.
210,000	Texas & Pac. Ry. gen. and ref. 5s.			1953	J-J	204,944.25
100,000	Toledo & Ohio Central Ry. Co. ref. & imp. 2½s.			1977	A-O	212,842.50
2,084,000	Union R. R. deb. 5s.			1960	J-D	90,000.
140,000	Union Pac. 1st lien and ref. 4s.			1946	J-J	2,094,000.
99,000	Union Pac. R. R. 4s.			2008	M-S	128,722.50
200,000	Va. Ry. Co. 1st 5s (\$100,000 reg. as to principal).			1968	J-D	87,900.63
40,000	Wabash R. R. Co. 1st 5s.			1962	M-N	206,535.50
300,000	Wabash Ry. ref. and gen. 5s.			1939	M-N	37,750.
100,000	West Shore R. R. Co., 1st Mtg. 4s.			1970	F-A	203,280.
200,000	Western Md. R. R. 1st 4s.			1940	J-J	75,140.
				1932	A-O	182,100.
13,422,000	Railway Sub. Total.					
						13,002,013.27

Schedule of Securities—Continued

Aggregate Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Prima. Int.	Prima. Only			
	<i>Public Utility</i>					
\$100,000	Ala. Power Co. 1st ref. 4½gs			1967	J-I	\$87,265.
212,000	Ala. Power Co. 1st & ref. 5s			1968	M-S	202,322.50
125,000	Am. Tel. & Tel. Co. sink. deb. 5½gs			1963	M-N	130,202.62
220,000	Am. Tel. & Tel. Co. deb. 5s			1960	J-J	225,800.67
265,000				1965	F-A	265,865.53
300,000	Appalachian Electric Power Co. 1st ref. 5s (\$50,000 registered as to principal)		*	1936	M-N	296,125.
300,000	Ark. P. & L. Co. 5s			1956	A-O	292,512.50
172,000	Bell Tel. Co. of Canada 1st "			1955	M-S	177,207.50
100,000				1937	J-I	101,125.
300,000	Birmingham El. Co., 1st ref. 4½gs			1908	M-S	283,056.25
75,000	Blackstone Valley Gas & E. 5s			1952	A-O	70,781.25
50,000	Brooklyn Edison Co., gen. mtg. 5s			1952	J-J	48,375.
300,000	Carolina Power & L. Co. ref. 5s			1936	A-O	302,208.75
110,000	Cedar R. Mfg. & P. Co. 1st sink. 5s			1933	J-J	109,500.50
125,000	Cincinnati Gas. & E. 1st 4s			1908	A-O	111,710.72
380,000	Columbia Gas and Elec. Corp., deb. 5s			1961	J-J	379,762.50
245,000	Columbus Rwy., P. & L. 4½gs			1937	J-J	233,454.87
77,000	Comm. Edison, 1st Mtg. 5s			1931	J-I	82,680.15
158,000				1981	M-S	115,465.40
60,000	Consolidated Gas Co. of N. Y. deb. 5s			1957	J-J	59,280.
100,000	Detroit Edison gen. & ref. 4s			1965	A-O	103,500.
150,000	Detroit Edison gen. ref. 5s			1962	F-A	155,825.
325,000	Ela. Power Co. 1st ref. 5s			1967	M-S	320,112.50
300,000	Eastman Power, 1st 5s			1936	J-I	298,750.
45,000	Great Western Power Co. 1st Mtg. sink. 5s			1940	J-J	45,003.31
100,000	Gulf States Util. Co. 1st 5s			1956	M-S	94,537.50
100,000	" " 1½gs			1961	J-I	91,250.
65,000	Hackensack Water Co., Gen. & Ref. 5½gs			1977	J-J	69,868.75
100,000	Houston Ltg. & Power Co. 1st lien & ref. 4½gs			1981	J-I	98,375.
100,000	Idaho P. Co. 5s			1917	J-J	100,750.
200,000	Illinois P. & L. 1st & ref. 5s			1936	J-I	198,750.
200,000	Indianapolis P. & L. 1st 5s			1957	J-J	198,806.25
200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s			1935	M-S	202,182.50
300,000	Inter. Tel. & Tel. deb. 4½gs			1952	J-J	288,250.
280,000	Int. Rap. Trans. ref. 5s	*		1906	J-J	278,701.
43,000	Kan. City P. & L. 1st 4½gs			1961	F-A	39,045.
13,000	Louisiana Power & Light Co., 1st 5s			1937	J-I	13,837.50
125,000	Louisville G. & Elec. 1st & ref. 5s			1952	M-N	121,468.75
300,000	Memphis P. & L. 1st & ref. 4½gs			1978	A-O	279,250.
93,000	Metropolitan Edison Co., 1st 5s			1962	M-N	97,740.
300,000	Milwaukee P. R. & L. ref. & 1st 5s			1961	J-I	302,387.50
100,000	Minn. P. & L. 1st & ref. 4½gs			1978	M-N	92,156.25
100,000	Montana Power Co., 1st & Ref. 5s			1913	J-J	90,787.50
108,000	Narransett B. Co. 1st 5s			1937	J-J	108,280.40
50,000	Newark Cons. Gas Co., Cons. Mtg., 5s			1918	J-I	50,770.
52,000	N. Eng. Tel. & Tel. 5s	*		1952	J-I	51,718.
100,000	New Orleans Pub. S. 5s			1935	J-I	99,200.
42,000	N. Y. Civ. B. L. H. P. pur. mon. 4s	*		1940	F-A	34,680.50
65,000	N. Y. & Westchester Ltg. 5s			1951	J-J	67,052.50
300,000	New York P. & L., 1st 4½gs			1967	A-O	286,125.
62,000	Niagara Falls P. Int. & com. 5s			1930	J-J	64,166.31
22,000	" " 5s			1930	M-N	23,800.
150,000	Northern Ind. Pub. S., 1st ref. 5s			1906	M-N	152,887.50
77,000	Northern Ohio Traction & L. gen. & ref. 5s			1947	M-S	79,143.17
78,000	Northern States P. 1st ref. 5s			1941	A-O	77,773.41
200,000	No. States Power Co., ref. 4½gs			1961	A-O	195,000.
22,000	No. States Power Co., 1st & Ref. 5s			1941	A-O	23,238.85
175,000	Ohio Power Co., 1st and ref. 4½gs			1956	J-I	163,439.06
50,000	Ohio Public Serv. Co., 1st & Ref. 3½gs			1961	M-N	60,813.75
50,000	" " 5s			1953	M-S	54,455.
200,000	Okla. G. & E. 1st 5s			1950	M-S	200,000.
100,000	Pac. G. & E. Co., 1st & ref. 4s			1964	J-I	104,000.
100,000	" " 4½gs			1960	J-I	107,000.
100,000	Pac. G. & E. Co. gen. & ref. 5s			1942	J-J	98,392.77
25,000	Pac. Tel. & Tel. 5s			1932	M-N	26,187.50
100,000	Penn. Electric Co., 1st & Ref. 5s			1962	A-O	98,632.50
300,000	Penn. Power & L. Co., 1st mtg. 4½gs			1941	A-O	289,562.50
105,000	Penn. W. & P. 1st ref. 4½gs			1908	M-S	102,597.06
207,000	Phila. B. Co. 1st & ref. 4½gs			1967	M-N	208,470.60
50,000	" " Mtg. sink. 5s			1968	A-O	56,500.
136,000	Pub. Serv. Co. of Indiana, 1st & ref. 5s			1952	F-A	119,540.
70,000	Pub. Serv. of No. Ill. 1st Lien & Ref. 4½gs			1981	A-O	66,655.
160,000	Pub. Serv. of No. Ill., 1st ref. 5s			1956	A-O	167,550.
60,000	Puget Sound Power & L. 1st & ref. 4½gs			1930	J-I	66,550.
50,000	" " 5½gs			1949	J-I	51,900.
82,000	Rochester Rwy. & L. 5s			1964	J-J	80,585.
75,000	Rochester Gas & Elec. Corp. gen. 5s			1962	M-S	69,475.
10,026,500	Forward.....					10,703,905.98

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int	Princ Only			
	<i>Public Utility</i>					
\$10,928,500	Brought Forward.....					\$10,705,005.98
300,000	Shawinigan W. & P. 1st & coll 4 1/2s			1907	A-O	286,212.50
50,000	So. Bell Tel. & Tel. 1st sink. 5s			1941	J-J	47,687.50
200,000	So. Calif. Edison Co., ref. 3 1/4s			1900	J-J	197,000.
52,000	So. Calif. Tel. Co. 1st ref. sink. 5s			1917	M-N	48,627.50
36,000	Syracuse Lighting Co. 1st and ref. 5 1/2s			1951	F-A	37,807.10
125,000	Tenn. Elec. P. Co. 1st and ref. 5s			1956	J-D	127,037.50
300,000	Texas Electric Service, 5s			1960	J-J	292,700.
200,000	Texas Power & Light Co. 1st & ref. 5s			1956	M-N	205,143.75
120,000	Toledo Edison 1st. Mtg. 5s			1902	M-N	115,800.
255,000	Union Elec. Light & Power Co. 5s			1907	F-A	259,024.05
220,000	Utah L. & T. Co., ref. 5s			1944	A-O	215,193.
233,000	Washington Water Power Co., 1st and gen mtg. 5s			1960	J-J	237,496.87
100,000	Western United Gas & Electric Co., 1st Mtg. 5 1/2s			1953	J-D	103,187.50
13,119,500	Public Utility Sub-Total.....					12,840,823.25

<i>Mortgages</i>						
25,000	Empire Title and Guarantee Co., Guar- anteed 1st Mtg., Ctf. No. 1678 5%.....	*		1939	FMAN	25,000.
100,000	Lawyers Mtg. Co. Guaranteed 1st Mtg. Cfcs, Series 18397 5 1/4%	*		1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5 1/4% Mortgage.....	*		1935	A-O	80,000.
100,000	1st Mortgage 1184 Cromwell Ave., N. Y. 5 1/4%	*		1932	M-S	99,500.
100,000	1st Mtg. N. W. cor. Westbury Ct. & Flat- bush Ave., Brooklyn 5 1/4%	*		1933	M-N	100,000.
100,000	Mortgage-Bond Co. of N. Y. 5s (Certificate of Deposit)	*		1938	J-D	96,000.
90,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctf., 5 1/4%	*		1938	A-O	90,000.
100,000	N. Y. Title & Mtg. Co. 1st 4 1/4s	*		1940	J-D	100,000.
100,000	Title Guarantee and Trust Co., 1st Mtg. Ctf. 130037 3% Participating	*		1939	J-D	100,000.
795,000						790,500.

<i>Industrial</i>						
25,000	Addressograph-Multigraph Corp. Deb. 5 1/2s			1945	A-O	25,000.
154,000	Aluminum Co. of A. 1st sink. deb. 5s			1952	M-S	151,826.07
100,000	American I. G. Chemical Corp., conv. 5 1/4s			1919	M-N	105,861.25
50,000	American Radiator Co., deb. 4 3/4s			1917	M-N	49,125.
50,000	American Rolling Mill Co., Conv. Deb. 4 1/2s			1915	M-N	50,000.
100,000	Bethlehem Steel Corp., Cons. sink. fund 4 1/4s			1960	J-J	98,500.
28,000	Gulf Oil Corp., sink. deb. 5s			1917	F-A	28,338.90
110,000	Lacka, Steel conv. 1st 5s			1950	M-S	112,925.
74,000	Midvale S. & O. conv. 5s			1936	M-S	74,161.38
49,000	National Dairy Proprs. Corp. Deb. 5 1/4s			1944	M-A	50,280.25
8,000	Park & T. Co. sink. deb. 6s					400.
78,000	Phillips Petroleum Co., sink. deb. 5 1/4s					78,000.
200,000	Rwy. Express Agency, 5s					198,42
100,000	Remington Rand Inc., deb. 5 1/4s					100,000.
100,000	Shell Manufacturing Co., Conv. deb. 5 1/4s					100,000.
200,000	Shell Pipe Line Corp., sink fund deb. 5s					192,50
54,000	Shell Union Oil Corp., sink. deb. 5s					54,000.
100,000	Skelly Oil Co., sink. deb. 5 1/4s					100,000.
100,000	Sococony Vacuum Oil Co., Deb. 3 1/2s			1950	A-O	100,000.
1,975,000	Tenn. C. I. & R. Co. Gen. Mtg. 5s			1951	J-J	1,975,000.
150,000	Tex. Corp. Sinking deb. 5s			1944	A-O	144,125.70
200,000	Youngstown S. & Tube 1st sink. 5s			1978	J-J	170,897.75
4,005,000	Industrial Sub-Total.....					3,987,005.57

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ Only			
Foreign						
\$120,500	German External Loan of 1921 7s.....	.....	.....	1940	A-O	\$128,738.53
100,000	Govt. of Argentine 6s.....	.....	.....	1960	M-S	97,625.
115,000	Imp. Japanese Govt. 5½s.....	.....	.....	1965	M-N	103,212.50
300,000	Kingdom of Denmark, ext. 4½s.....	.....	.....	1982	A-O	274,375.
25,000	City of Montreal 5s.....	.....	.....	1956	M-N	24,062.50
75,000	City of Montreal sink 5s.....	.....	.....	1954	M-N	72,375.
100,000	City of Montreal 4½s.....	.....	.....	1946	F-A	94,368.90
200,000	New South Wales, ext. 5s.....	.....	.....	1958	A-O	189,562.50
100,000	Province of Alberta deb. 4½s.....	.....	.....	1958	J-J	93,750.
100,000	Province of Alberta 5s.....	.....	.....	1950	A-O	101,125.
200,000	Province of Manitoba deb. 4½s.....	.....	.....	1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s.....	.....	.....	1952	M-S	100,312.50
100,000	Province of Ontario 4s.....	.....	.....	1964	M-N	87,150.10
80,000	Province of Ontario 5½s.....	.....	.....	1937	J-J	61,293.09
100,000	Province of Ontario 5s.....	.....	.....	1959	M-N	99,789.63
40,000	Province of Ontario 6s.....	.....	.....	1943	M-S	43,137.50
30,000	Prov. of Saskatchewan deb. 5s.....	.....	.....	1943	J-D	30,627.44
74,000	Toronto Harbour Comm. 4½s.....	.....	.....	1953	M-S	71,101.87
100,000	City of Toronto con. deb. 6s.....	.....	*	1940	J-D	98,152.42
90,000	City of Toronto, 5s.....	.....	.....	1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s.....	.....	.....	1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s.....	.....	.....	1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s.....	.....	.....	1946	J-D	95,375.
2,320,500	Foreign Sub-Total.....	.....	.....	.....	.....	2,245,733.51
State and Municipal						
50,000	City of Cleveland, Water Works, 5½s.....	.....	.....	1967	M-N	52,984.80
25,000	City of Detroit, Water Supply, 4s.....	.....	.....	1955	J-D	24,812.50
25,000	City of Detroit, 4½s.....	.....	.....	1952	M-S	25,250.
50,000	City of Newark, Street Opening, 5½s.....	.....	.....	1958	F-A	51,724.94
50,000	City of New York, 4½s.....	.....	.....	1981	M-S	50,125.
50,000	City of New York, 4½s.....	.....	.....	1979	J-D	51,750.
84,000	State of North Carolina, Highway, 4½s (\$30,000 registered).....	*	.....	1953-63	J-J	92,819.50
50,000	City and County of San Francisco, Hetch Hetchy, 5½s.....	.....	.....	1960	J-D	53,523.34
384,000	State and Municipal Sub-Total.....	.....	.....	.....	.....	402,989.88
Stocks						
50,000	A. T. & S. Fe pref. stock.....	*	.....	.....	F-A	52,125.
200,000	Cons. Gas. Co. Cum. pref. stock.....	*	.....	.....	FMAN	198,725.
100,000	Du Pont de Nemours, deb. Stock.....	*	.....	.....	JAJO	110,125.
50,000	J. I. Case Thresh. M. Co. pref. stock.....	*	.....	.....	JAJO	62,225.
40,000	Union Pac. R. R., pref. stock.....	*	.....	.....	A-O	33,415.
500,000	U. S. Steel Corp., pref. stock.....	*	.....	.....	MJSD	715,173.50
940,000	Sub-Total..... Stocks.....	.....	.....	.....	.....	1,177,788.50
34,995,000	Aggregate - Funds Invested.....	.....	.....	.....	.....	34,486,943.98

Real Estate and Equipment, Original Cost

<i>Administration (October 31, 1935)</i>			
<i>Washington, D. C.</i>			
Building, site, and equipment.....			\$404,526.96
<i>Division of Plant Biology (September 30, 1935)</i>			
<i>Palo Alto, California (Headquarters)</i>			
Buildings and ground.....	\$151,757.02		
Laboratory.....	52,698.39		
Library.....	26,233.68		
Operating appliances.....	25,072.03	258,751.12	
<i>Department of Embryology (September 30, 1935)</i>			
<i>Wolfe and Madison Sts., Baltimore, Md.</i>			
Library.....	3,191.02		
Laboratory.....	13,737.03		
Administration.....	6,814.48	23,745.53	
<i>Department of Genetics (September 30, 1935)</i>			
<i>Cold Spring Harbor, Long Island, N. Y.</i>			
Buildings, grounds, field.....	291,461.28		
Operating.....	30,177.21		
Laboratory apparatus.....	25,002.75		
Library.....	42,310.27		
Archives.....	45,488.90	434,560.44	
<i>Geophysical Laboratory (September 30, 1935)</i>			
<i>Upton St., Washington, D. C.</i>			
Building, library, operating appliances.....	218,601.80		
Laboratory apparatus.....	148,609.61		
Shop equipment.....	16,426.37	383,640.87	
<i>Division of Historical Research (September 30, 1935)</i>			
<i>Tower Building, Washington, D. C.</i>			
Operating.....	14,769.41		
Library.....	7,702.22	22,470.63	
<i>Tortugas Laboratory (September 30, 1935)</i>			
<i>Tortugas, Florida</i>			
Vessels.....	30,030.43		
Buildings, docks, furniture, and library.....	12,930.86		
Apparatus and instruments.....	9,322.65	53,183.84	
<i>Department of Meridian Astronomy (September 30, 1935)</i>			
<i>Dudley Observatory, Albany, N. Y.</i>			
Apparatus and instruments.....	4,816.84		
Operating.....	5,273.08	10,120.52	
<i>Nutrition Laboratory (September 30, 1935)</i>			
<i>Vila St., Boston, Massachusetts</i>			
Building, office, shop and library.....	132,878.40		
Laboratory apparatus.....	37,050.38	169,928.78	
<i>Mount Wilson Observatory (September 30, 1935)</i>			
<i>Pasadena, California</i>			
Buildings, grounds, road, and telephone line.....	202,539.72		
Shop equipment.....	46,032.98		
Instruments.....	667,173.18		
Furniture and operating appliances.....	200,670.83		
Hooker 100-inch reflector.....	606,983.41	1,723,309.12	
<i>Department of Terrestrial Magnetism (September 30, 1935)</i>			
<i>5841 Broad Branch Road, Washington, D. C.</i>			
Building, site, and office.....	226,734.09		
Survey equipment.....	102,611.45		
Instruments, laboratory, and shop equipment.....	170,994.63	500,340.17	
		3,984,577.98	

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON
FOR THE YEAR ENDING OCTOBER 31, 1935

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

In accordance with established procedure, the President has the honor to transmit to the Trustees of Carnegie Institution of Washington the following report on progress of activities in the Institution for the year ending October 31, 1935.

At a time when interest in the great constructive work done by Mr. Carnegie in various fields of education, science, and culture is emphasized by the one hundredth anniversary of his birth, it is fitting that there be included in this report reference both to the original aims in founding the Institution and to the trend of activities which will determine ultimate appraisal of accomplishment. In considering this relation between aims and achievement, one may not avoid noting that the Year Book series in which this report appears is the most comprehensive statement in existence regarding work of the Carnegie Institution. The thirty-four volumes of this series constitute a detailed report and a history of activities initiated by the Institution since the date of its founding in 1902.

The objectives of an agency like the Carnegie Institution can not be defined with such mathematical clearness as to permit adequate report in statistical form. But without evident appreciation of purposes or aims a statement concerning development of the activities might have relatively little value. Although the purposes of the Institution are known in general terms through reports upon its researches, there may be marked difference between a statement to the effect that something has been done and

a record formulated with relation to objectives. A report properly requires examination of the program as it has developed and of achievement in terms of the ideas visioned by the Founder.

In the long list of activities to which Mr. Carnegie devoted his efforts, the use of opportunities considered most desirable found expression in many kinds of institutionalized programs. The purposes defined appeared to vary widely, though in many ways these apparent differences were only the statement, by various means, of basic ideas which guided Mr. Carnegie's thought. The whole group would probably have been found closely related in his view of the greatest needs of the time.

In the decision that large personal possessions should, so far as possible, be turned to use in the interest of the people, for furtherance of major ideas urgently needing intensive support, Mr. Carnegie emphasized, among other things, dissemination of knowledge through the library, and the study of fundamental educational problems and economic security of the teacher through the Carnegie Foundation and the plan for teachers' pensions. Art, the museum, technology, and education broadly were furthered by Carnegie Institute, at Pittsburgh. Self-sacrifice and courage were recognized through the Hero Fund in the United States and similar funds abroad. Study of difficult, but vastly important, problems of world relations and peace was the objective of the Endowment for International Peace. As concrete projects relating to what seemed of immediate importance, he aided the peace movement through building the Palace of Peace at The Hague and establishment of the Church Peace Union. To provide opportunity for conference and discussion on in-

ternational problems of the Americas, he made possible the home of the Pan American Union in Washington and of the Central American Court of Justice in Costa Rica.

For the immediate benefit of the community in which he was born, for the advancement of education, and for the well-being of people of Great Britain and Ireland, Mr. Carnegie established the Carnegie Dunfermline Trust, the Trust for the Universities of Scotland, and the United Kingdom Trust.

Along with the splendid group of activities already mentioned, the Carnegie Institution of Washington was founded on January 28, 1902, "to encourage in the broadest and most liberal manner investigation, research, and discovery, and the application of knowledge to the improvement of mankind." In 1911 the Carnegie Corporation of New York, representing broadly the general activities in which Mr. Carnegie had been engaged, received the remaining large means for aiding in such projects as might be considered worthy of support in promoting "the advancement and diffusion of knowledge and understanding among the people of the United States," and with these means for benefaction was included a special fund of ten million dollars available for activities in the British Dominions and Colonies.

Appreciating the necessity for uninterrupted advancement of knowledge and intellectual growth, for realization of which continued investigation, research, and discovery would be required, Mr. Carnegie saw also the need for maintaining study of the methods by which such advance could best be made. The organization and planning of the Institution were, therefore, so designed as to leave freedom of action such as would make possible the most effec-

tive development of program in the light of changing conditions. This was recorded in Mr. Carnegie's statement: "The specific objects named are considered most important in our day, but the Trustees shall have full power, by a majority of two-thirds of their number, to modify the conditions and regulations under which the funds may be dispensed, so as to secure that these shall always be applied in the manner best adapted to the changed conditions of the time; provided always that any modifications shall be in accordance with the purposes of the donor, as expressed in the Trust, . . ."

With reference specifically to the objectives which Mr. Carnegie had in mind in establishing the Institution, it is important to note that there was involved both the idea of research and discovery in the sense of acquaintance with new materials and new ideas, and with this the desire "to expand known forces, to discover and utilize unknown forces for the benefit of man." It is interesting to observe that the expression of purpose did not end with the idea that this was merely for the *benefit* of mankind, but the activity was stated to include as well "discovery, and the application of knowledge to the *improvement* of mankind."

A student of history might incline to interpret Mr. Carnegie's statement regarding "improvement" as meaning that he expected the human race to better itself continually through an evolutionary process. Whether or no this was specifically the idea in mind, it is clear that Mr. Carnegie thought not only of the "expanding of known forces and the discovering of unknown forces," but that he had in view activity leading to continuing development and improvement. Whatever views we may entertain as to ulti-

mate good in the philosophical or religious sense one may not doubt that the idea of forward movement in the wider range of knowledge, of better means of application for human use, and of uninterrupted growth in intellectual as well as in spiritual stature, represents a condition offering an infinite range of achievement and of hope. However other goals may be defined, the way leading to a place or a condition with evident possibilities for improvement will be looked upon as having special importance when it offers opportunity for progress leading to more progress.

DEVELOPMENT IN METHODS AND ORGANIZATION OF RESEARCH IN THE INSTITUTION

As has been indicated in many earlier reports to the Trustees, the work of the Institution was initiated with numerous relatively small grants which were commonly made available to individuals. By this means it was possible to select both outstanding projects which needed special support, and exceptional individuals whose ability and interest it was important to have turned toward constructive study.

In the preparation of a working program for the Institution which should give effect to the purposes of the Founder, the Board of Trustees upon organizing in January, 1902, appointed eighteen advisory committees, each committee representing a recognized department of knowledge. These committees were invited to canvass the needs in their respective fields and to make such recommendations relative to procedure as they believed would "advance with wisdom the great purpose of the foundation." It is to the reports of these committees—reports that sought to give definitive expression to the vision of the

Founder—that Carnegie Institution, as it now stands after 34 years of growth, traces its roots. The published reports of these committees represent in themselves an extremely interesting stage in the development of research in America.

The Institution of today differs in some measure from the Institution of early years in administrative structure, in method of work, in program of research, and in relationship to educational and investigational agencies as well as to the general public. Yet the changes that have ensued are but progressive responses to altered conditions, on the one hand, and to slow but steady conquest, on the other.

That the Institution today, with all its differences, remains as much an expression of the Founder's ideals as it was thirty years ago is remarkable attestation to the breadth of the Founder's vision and to his great wisdom in creating an organization sufficiently flexible to adapt itself to situations that are ever changing.

In considerable measure as the result of studies by the special committees, work was initiated upon projects which required concentration of interest and effort of groups of specialists concerned with major problems. As this evolution of method and organization advanced, to some it may have appeared to lead toward a situation quite different from that suggested through Mr. Carnegie's original ideas.

But what seemed to be a fundamental shift in program leading to support of larger projects, and to the coöperation of considerable groups of individuals, has in some respects tended to emphasize significance of the exceptional man more than might have been done by continued use of the smaller grants to individuals conducting their

researches independently. Organization of departments, and ultimately of divisions, while appearing to require sharper definition of limits for individual activities, has served to bring about concentrated attack by individuals having specific interests in common problems the solution of which could be obtained only by such coöperative effort. In some respects the results have brought increased opportunity for the individual with exceptional vision and leadership, and at the same time have increased the possibilities of advance in research for others with intense enthusiasm and showing exceptional devotion to research.

Illustration of the type of activity which developed in departments is found in the organization of the Geophysical Laboratory, Mount Wilson Observatory, and the Department of Genetics.

In the Geophysical Laboratory, established in 1907, a group of researches was turned toward what has sometimes been called the dark continent of the interior earth. Requisitioned to this service, every value which could be derived by application of chemistry, physics, geology, volcanology, and ultimately seismology, has been used in study of a region in some ways more difficult to reach than the stellar universe about us. Another illustration of this method in the physical sciences is that presented by Mount Wilson Observatory, founded in 1904, and dedicated to the study of the sun, as the star most easily accessible for observation by telescope, spectroscope and all instruments which can give us knowledge of the morphology, physiology, chemistry, and physics of that great physical unit upon which the existence and development of life on the earth depend.

Still another illustration of necessary coöperative effort is found in establishment of the Department of Genetics, originally set up as the Station for Experimental Evolution in 1904 and later combined with Eugenics. Upon the intimate study of lines of inheritance, and the factors involved in development of the individual, and the origin of the species and related groups, there has been concentrated the life work of many individuals operating through what have seemed widely different regions of investigation, but which are all concerned with the nature and mechanism of individual and racial or group evolution.

In 1927, several phases of related Institution activities in plant biology were brought together in a Division comprising a wide range of problems extending from experimental taxonomy through ecology, investigation of desert problems, basic studies on the biology of tree growth, relation of climatological research to periodicity in tree growth, problems of photosynthesis, and palæobotany. Brought into this close relation, new and important developments in plant study have been made possible.

A Division of Historical Research was established in 1929 to bring into the most effective relation groups of studies covering aboriginal American history, a section concerned with the history of the United States as expressing the influence of western European institutions upon America, and a third section comprising studies in the history of science with special reference to its influence upon civilization. To these researches is related a considerable group of studies concerned with the early history of man as it is read from the geological record.

In 1934 a Division of Animal Biology was established as the natural outgrowth of effective and fruitful confer-

ences, covering research in genetics, nutrition, embryology, with other aspects of biology including a wide group of activities held together by interest in many common problems.

Within the past year the continuing importance of relations among the organized activities of the Institution in the field of the physical sciences has led to setting up of a committee to facilitate study on the increasing number of common problems appearing in these fields. This committee will also make more easily possible the development of special projects representing interests of several departments.

The contributions already made through coöperation of groups of investigators in the physical sciences have been extremely valuable, and with the rapid shift of emphasis in physical problems one may expect continuing development of new fields requiring special facilities for investigation. In the physical sciences, as in the other research groups of the Institution, it is assumed that better definition of facilities for interchange of data and for coöperation will aid in solution of problems requiring concerted action by representatives of rather widely differing disciplines or modes of approach.

Good illustrations of what may be accomplished in such coöperation are found in the study of relation between solar activity and radiation, at Mount Wilson Observatory, and variations in magnetic conditions on the earth, forming the subject for continuous investigation by the Department of Terrestrial Magnetism in Washington. The noteworthy contributions by the Moon Committee, involving several departments together with investigators from other institutions, have not only given us a better

understanding of the moon, but have furnished data of value in study of the surface of the earth and of other planets.

One of the most important achievements in the field of Institutional activities involving concerted effort of several institutions is represented by the Seismological Laboratory at Pasadena, planned and developed through the work of the Advisory Committee in Seismology under the chairmanship of Dr. Arthur L. Day, Director of the Geophysical Laboratory. Although seismology may well be claimed as a phase of geology, comprising as it does the study of inner features of the earth, the work of this laboratory was organized on the basis of coöperation with the geological, physical, and mathematical groups at California Institute of Technology and other institutions. Under the wise guidance of the Advisory Committee, many types of interests have been directed toward study of earth movements, and have made possible achievements of exceptional significance. The ultimate values in what has been obtained through this unique project, involving coöperation of many agencies and institutions, make a contribution of unusual interest in very many directions, and are of great aid to the Geophysical Laboratory itself, concerned as it is with physics and chemistry of the inner earth.

The present organization of the Institution seems, then, not only to contribute toward advance of knowledge in new interlocking or overlapping areas of research, but to bring back to each of the groups engaged upon special questions a wide range of materials otherwise not readily secured.

In other phases of activity of the Institution the

grouping of interdependent researches has been of great significance, in that this type of organization has also facilitated mutual aid between divisions as, for example, in study of problems in Eugenics.

In still another way this plan of organization has furnished means for satisfactory handling of those more sharply individualized projects known as Minor Grants, corresponding to the means of aid for research mainly utilized in the early stages of the Institution's activities. This support was given with expectation that it would either assist the exceptional individual, or advance study of an exceptional problem investigated by students of recognized ability. As the number of these grants increased, with passing of the years some researches shifted quite naturally to new aspects of investigation, and the problem of keeping touch with work of this type became increasingly difficult. With a divisional program of administration, large value has been found in the relation of Minor Grant projects to the divisions, thus giving not only the aid of special funds, but with this the support also of a group of workers interested in various aspects of the projects undertaken.

The possibilities for assistance through use of the present grouping of activities have been illustrated in the work of Dr. Ernest Anderson, of the University of Arizona, who has coöperated for several years with the Institution through the Division of Plant Biology at its laboratory in Palo Alto. The work of Dr. Anderson in study of the chemistry of tissues in tree growth has related itself to that of Dr. I. W. Bailey, of the Bussey Institution of Harvard University, who has coöperated with the Division of Plant Biology for several years in furtherance of

studies on morphology and chemistry of structures involved in tree growth. In another very important relation, the fundamentally critical work of Dr. Bailey on tree growth has been extremely helpful in furnishing through the Division of Plant Biology a biological background for the researches of Dr. A. E. Douglass on changes in the course of tree growth as expressed in tree rings.

PHYSICAL SCIENCES

In the investigations conducted by Carnegie Institution in the physical sciences, there has been maintained constantly the idea that it is a function of the Institution to devote itself to projects of such magnitude, or of such difficulty in handling, that advance is facilitated through research by an agency free to attack at such a place, or such time, or by such method as seems most desirable. While the work of the Institution has in large part taken form through well-organized and extremely effective departments, such as, Geophysical Laboratory, Department of Terrestrial Magnetism, and Mount Wilson Observatory, a number of the most significant investigations have been conducted by smaller groups, as in the case of the Seismological Laboratory and of investigations in the field of cosmic-ray research.

Although in projects of the Institution in the physical sciences, even where they are set up through the organization of departments, attempt is made to avoid the tendency merely to discuss broad subjects rather than undertake specific investigations, it will be noted that the several fields entered comprise types of research touching a considerable part of the physical universe. This is true in the geographic sense measuring from the center of

the earth to the most remote nebulae, as also in the range from study of structure in the atom in its relation to problems of terrestrial magnetism to discussion of the nature and dimensions of the universe. So it happens that while the Institution does not devote itself directly to the generalized problem of knowledge in the broader educational sense, it is forced by the nature of its researches to include discussion of a considerable part of all phenomena encountered.

GEOPHYSICAL LABORATORY

The problems of the Geophysical Laboratory, concerned as they are with the basic composition and structure of the earth, have been stated in the form of results through a great number of technical papers, and in a series of exceptional monographs, including such publications as Perret's "The Vesuvius Eruption of 1906," Day and Allen's "The Volcanic Activity and Hot Springs of Lassen Peak," and, more recently, Perret's "The Eruption of Mt. Pelée 1929-1932," and the monograph on "Hot Springs of the Yellowstone National Park" by Allen and Day.

The general problem of the Geophysical Laboratory representing its activities as developed since 1907 is presented in an exceptionally effective form of statement by the Director, Dr. Arthur L. Day, in the introductory paragraphs of his annual report of 1935, from which the following quotation is taken:

The help which physics and chemistry can give to the study of rocks and the processes of their formation is necessarily limited by the fact that only the thinnest layers of these rocks forming the exposed surface of the earth are accessible. Underlying materials from which the pres-

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ent surface rocks were doubtless formed and in which similar formation processes may now be going on are quite out of our reach below a depth of approximately one mile. Below that point in most regions, even if we were able to provide an opening, temperatures would be too high for human approach. In these circumstances the geologist naturally turns to the volcanoes through which samples of deep-seated material are brought to the surface, often in fluid or gaseous condition, from which much may be learned.

The study of volcanoes may be approached in three of their phases, though not equally well in all. The violent phase of volcanism in which explosive activity and lava outpourings commonly occur is inaccessible to near approach and moreover is often of such short duration that successful studies with competent equipment are rarely possible. There are types of volcanoes, like Kilauea in the decade immediately preceding 1924 during most of which time a lava lake some 500 feet in diameter maintained a more or less constant activity, in which fluid lava may be successfully approached. Taking advantage of this opportunity, students from the Geophysical Laboratory actually succeeded in collecting gases directly from the molten lava without contamination by atmospheric air. Out of this investigation it became clear for the first time that the behavior of lava during eruption was largely dominated by its gas content and that gaseous ingredients were a normal and regular part of its composition, notwithstanding the fact that the older rocks bear but inadequate evidence today either of the total amount or of the original proportions of the gases which must have participated in their formation. In 1924 the quantity and activity of the gases at Kilauea became such as to blow out the entire crater and its setting, enlarging the opening to something like a ten-fold volume and lowering the bottom out of reach of human approach. Thus ended the opportunity for intimate study of an active lava crater for the time being.

During the past year the effort has been made to continue these studies in Central America where several volcanoes are more or less continuously active, but the violence of their behavior is such as seriously to limit the possibilities of physical and chemical study. Nevertheless, collections have been made in this region and some measurements which will be reported upon after opportunity has been given for their study.

Still a third attempt has been in progress during the past three years at the well-known crater of Mt. Pelée in Martinique. It will be recalled

that in 1902 this volcano broke out in active eruption with initial explosions of such violence and direction as to effect the complete destruction of the city of St. Pierre and of all its thirty thousand inhabitants except two. Something over three years ago signs of renewed activity developed in which most of the explosive phenomena of the earlier violent phase were repeated upon a somewhat milder scale which rendered them approachable with some degree of success. Mr. Perrot's volume entitled *The Eruption of Mt. Pelée, 1929-1932* containing the results of painstaking and continuous observation during this period with modern equipment and his unique experience, is now in press and will appear during the present calendar year.¹

Such are the occasional opportunities which have been afforded to us to study crust-forming rock materials at the time of their ejection in fluid condition.

A second phase of volcanism of equal importance in its geological significance, though a step farther removed from ultimate causes, is represented by that state of waning activity when fumaroles and hot springs appear in volcano regions. Many valued ore deposits are commonly thought to have their origin in depositions from currents of hot gases (fumaroles) or from circulating hot waters. While such emanations are always approachable and often convenient for human study, they have heretofore usually been approached upon a basis of economic usefulness rather than of causal significance.

The third phase of volcano study is concerned with the volcano edifice as a recent formation after all activity has ceased.

SEISMOLOGICAL RESEARCH

The program of earthquake research initiated by the Carnegie Institution in 1921 through appointment of an Advisory Committee has carried its investigations in many directions. As a result of early surveys of the field, it was considered important to select an area where the phenomena of earth movement could be studied to advantage, and where there would be available adequate data represented in topographic and geologic maps, as also the possi-

¹ Carnegie Inst. Wash. Pub. No. 458.

bility of coöperation with investigators in those fields of research which might to advantage be utilized in a more intensive examination of earth movement.

Through coöperation with California Institute of Technology an exceptionally favorable site was obtained in Pasadena, and the building and grounds for the Seismological Laboratory were furnished by California Institute. After initial study of the field for several years, a conference of leading experts of the world, held in Pasadena in 1929, led to a clear focusing of the plan and mechanism for study and to the rapid development of a research program. The existing central station at Pasadena with its seven sub-stations as organized at the present time represents one of the most interesting opportunities that the world has known for examination of earth movement in relation to earth structure.

The fine coöperation of other research institutions, as represented by the United States Coast and Geodetic Survey, the University of California, Stanford University, and many others, has made feasible the furtherance of understanding regarding problems under investigation in ways not otherwise possible.

Recognition of the engineering value of all data secured by the researches of the Seismological Laboratory has brought extraordinary coöperation from Pasadena and the adjacent communities, and has made it possible to turn the scientific results almost immediately into data of large human value.

Among situations in which scientific research seems to have a definite relation to emotional reactions of the most extreme type, the problem of human values in seismology furnishes an interesting illustration.

In the midst of a multitude of influences which have tended to disturb the world balance of many situations in economics, government, and perhaps in fundamental beliefs, it has appeared to some that the influence of modern science has itself been one of the disturbing factors. From other points of view, the suggestion has come that the scientific mode of thought gives us one of the foundation stones upon which a future stable civilization may be built. The question whether science furnishes such an influence will be tested in a measure by study of cases in which examination is made of the effect of the scientific mode of approach upon fundamental thought, as also upon emotional reaction of individuals and of the masses.

Both in front-page articles and in editorial comment important newspapers have made abundant reference within the past weeks to disturbing influences of the earthquake which visited the east coast of the United States on November 1, 1935. Along with comment on the extent of property damage and the possibility of physical injury to human beings, frequent note was made regarding the effect in terms of hysteria and nervous disturbance. Although the earth movements along the Atlantic Coast were looked upon as probably not of great significance, attention was called to the fact that such phenomena carry the possibility of serious effect upon nervous states of people within the area affected.

Among the differences which separate modern civilized man from the type of being which we term the primeval savage, one of the striking contrasts is found in the degree of understanding of natural phenomena. With increasing knowledge of nature, of its forces, and of their action,

fear of the natural world has diminished. One of the last of the groups of phenomena inimical to human interests which we have come to understand is that represented in the earthquake. When the solid earth becomes unstable and the surface moves like the waves of the sea, foundations of the established order in our understanding of nature are disturbed. With the source of movement unknown, and arising from abysmal regions of the inner earth, of which we have little knowledge, the effect produced is a mingling of fear and uncertainty which readily reaches the level of hysteria. The contribution of seismology toward interpretation of what takes place in earth movements, with the further formulation of information as to how such dangers may be avoided, is in some respects one of the most important illustrations of the influence of science upon our interpretation of tremendous forces acting through nature, and of its effect upon our attitude toward the world about us.

Information as to some of the most recent activities in research at the Seismological Laboratory, and especially concerning contribution of work carried on in collaboration with the United States Coast and Geodetic Survey, is given in interesting form in the report of Dr. Arthur L. Day, Chairman of the Advisory Committee in Seismology, from which the following quotations are taken:

The investigation of nearby earthquakes, which was begun by the Advisory Committee in Seismology of the Carnegie Institution of Washington, has stimulated interest in other phases of earthquake study. Engineers have stressed the need for studies which will result in better design of buildings and other structures to resist earthquakes. During the fiscal year ending June 30, 1935, Public Works funds were provided, which made possible the study of vibration periods of buildings and other structures and of the ground. The plan of work was developed at

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a series of conferences, attended by engineers, architects and seismologists, several of which were held at the Seismological Laboratory.

Vibration measurements have now been made in two hundred and twelve buildings, on thirty-seven elevated water tanks, on one completed and two incomplete bridges, two dams, six pavement sites, and on several structures of special design. Through the loan of several Wood-Anderson seismometers by the Seismological Laboratory, this work was started at a much earlier date than would otherwise have been possible. These were modified for this work immediately following the Long Beach earthquake.

The measurement of ground periods by explosion or by shaking machine has been done to only a limited degree in California. The first comprehensive attack on the problem of ground periods has been the investigation at the Seismological Laboratory under the direction of Dr. Gutenberg of several thousand seismograms. These are from the five associated stations. The personnel employed in the measurement of the seismograms was provided by the Coast and Geodetic Survey.

In the strong-motion work begun by the U. S. Coast and Geodetic Survey in 1932, instruments have been operated throughout the length of California. Twenty-five records of nine earthquakes were obtained during the present year. In all earthquakes in the southern part of the state, the value of the records was enhanced by exact knowledge of the position of the foci, furnished by the Seismological Laboratory.

The principal data accumulated during the year will be summarized in one volume to be published by the Coast and Geodetic Survey. Among the authors are Beno Gutenberg of California Institute of Technology and Hugo Benioff of the Seismological Laboratory.

One phase of the work in a purely engineering field was a study of damage to buildings at Long Beach and adjacent towns. The work was under the direction of R. R. Martel, his party being provided by the Coast and Geodetic Survey.

It might be mentioned that a Wood-Anderson seismograph loaned by the Seismological Laboratory for temporary use at the Coast and Geodetic Survey at Sitka, Alaska, was brought to Washington for comparative tests, along with other instruments of high sensitivity, upon a shaking table at the Bureau of Standards. These tests of comparative behavior under like measured conditions will have general interest.

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One other activity that has been going on for a number of years is the collection of reports of visible and felt effects of earthquakes by volunteer observers in the west-coast region. This was originally carried on by the Seismological Laboratory for the southern half of California, but later the work was taken over by the Coast and Geodetic Survey.

The Coast and Geodetic Survey during the fiscal year ending June 30, 1935, has been actively engaged in extending the horizontal and vertical control nets over the country. More than a hundred thousand miles of first and second-order leveling were added to the vertical control survey net, making an approximate total of 250,000 miles in the country. About 17,500 miles of first and second-order triangulation were also added to the horizontal control net in the same period.

Work that is of special interest to seismology consists of three arcs of triangulation in California, totaling 300 miles in length. These three arcs are one along the Mexican boundary from El Central to San Diego, another from Lucerne Valley to Needles, and the third from Rice to Kingston.

A very intensive leveling survey was made at the request of the Chairman of the Advisory Committee in Seismology of the Carnegie Institution of Washington. It includes eight lines of closely spaced bench marks, approximately normal to various known fault lines in southern California. A number of these lines cross San Andreas fault in the vicinity of Maricopa, Bailey's Ranch, Palmdale, Cajon and Whitewater. Another line crosses the double San Jacinto fault in the vicinity of Armada. There is a line across the Whittier fault in the vicinity of Brea, and one across the Inglewood fault at Inglewood. Each of these lines extends for about five miles out from the fault in either direction. Bench marks were spaced at intervals of 100 feet for the first mile, at 200 feet for the second mile, 300 feet for the third mile, 400 feet for the fourth mile, and 500 feet for the fifth mile. This spacing was decided upon by the Advisory Committee in Seismology.

A year or more ago a network of lines of levels in the vicinity of San Jose, California, involving more than 200 miles of leveling, was established with a view to studying the reported subsidence of the area. This net was rerun in the autumn of 1934 and in the spring of 1935. It has not been possible to compute and adjust the work done in those two periods, but reports from the chiefs of the leveling party which carried on the field work indicate that the subsidence noticed in previous level-

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ing is continuing. It is hoped that within a few months it will be possible to make the computations and adjustments of all the leveling in the vicinity of San Jose.

Further work by the methods of geophysical prospecting has been conducted under the auspices of the California Institute of Technology. Dr. Buwalda and Dr. Gutenberg, aided by students of the Institute, did work of this kind in the Wyoming region and in Yosemite Valley with aid from the Geological Society of America, and work on Frazier Mountain and in the Los Angeles basin with funds obtained from local sources.

Under the direction of Dr. Gutenberg, a detailed investigation has been made by men working for the U. S. Coast and Geodetic Survey of the prevailing periods recorded on the seismograms of shocks in this region registered at our several stations. The results found are very consistent and will be published by the U. S. Coast and Geodetic Survey.

TERRESTRIAL MAGNETISM

Establishment of research in the field of terrestrial magnetism by the Institution concentrated in one group types of investigations which had been carried on as part of the research on compass directions and changes affecting navigation and, therefore, of interest to all civilized peoples. Founded as a laboratory for study in one of the most difficult regions of physical research, the work of this Department has made contribution of inestimable value in the general field of navigation as it relates to the compass and to magnetic fluctuations over the earth.

In another direction the work of this Department has served in a noteworthy manner to develop bonds of mutual interest among scientists, navigators, and those concerned with commerce over the seas. In the history of researches of this Department, it is extremely interesting to note that wherever these studies have been conducted the investigators have received the kind of encouragement and

coöperation which is properly given to fellow workers examining a question of mutual concern. Especially was this true in the course of investigations conducted by use of the ship *Carnegie*, sailing the seas of the world for a period of twenty years between 1909 and 1929. Among the many contributions made by Mr. Carnegie toward betterment of international relations, the assistance which he gave to science that made necessary the coöperation of peoples and nations for ultimate solution of problems has gone far to bring about the kind of understanding and of mutual interest essential in the foundations upon which peace may be built.

Activities of the Department of Terrestrial Magnetism, initiated with research on magnetic conditions over the earth as a whole, rapidly and naturally extended into study of a great variety of phenomena involving the meaning of magnetism, its relation to other forces expressed in the earth, in the atmosphere, and in the sun, and reached in still other directions into the most intimate details of structure and function of the atom. It became evident that it was necessary not only to know the range of magnetic and electric influences affecting the earth as a whole, and those forces which involve relation of the earth to the sun, but that with these it was essential that we broaden our knowledge of the nature of magnetism, and of the way in which forces residing in the atom are related to those involved in such problems as are illustrated in study of the earth as a magnet.

The personal handling of activities in the Department of Terrestrial Magnetism represents in a very extraordinary way the development of means for coöperation with other agencies in this country and over the entire world.

The development of facilities for working together on problems of common interest has involved not only the researches on terrestrial magnetism in the limited sense, but has extended to a wide reach of interests in many phases of the physical sciences. Not only has it been recognized that mutual aid is desirable among scientific investigators, but in development of this spirit of coöperation it has become apparent that much of what is needed for solution of many special problems of vital interest to this Department can come only through investigations conducted in other divisions of science.

As one of the more interesting illustrations of the importance of mutual aid, it appears that work done by the Department of Terrestrial Magnetism in study of biological problems in the course of the last voyage of the vessel *Carnegie* has not only contributed in an important way to biology, but that biology has made its return to physical science of the ocean by indicating, in the distribution of sensitive organisms, certain factors relative to the physical characters of the sea that otherwise might not have been discovered.

The aid of the Department of Terrestrial Magnetism has been given generously to the British Admiralty in its program for construction of a non-magnetic vessel to continue the magnetic survey of the sea originally carried on by the *Carnegie*. Reference to this important relation is described as follows in the Year Book report for 1935 of Dr. John A. Fleming, Director of the Department:

An outstanding event for geophysical science was the decision in March 1935 of the British Admiralty to construct a non-magnetic vessel—to be named *Research*—to continue the magnetic survey at sea of the *Carnegie*. Upon request of the Admiralty, plans and specifications

of the *Carnegie* and designs of instruments, as evolved during the many years of the Department's oceanic work, were supplied. Arrangements were completed that William J. Peters, who was for many years in command of the *Carnegie*, to go in the fall of 1935 to England as a consultant on the design and construction of the new vessel and of her instrumental equipment.

The annual report of the Department for the past year presents an extremely interesting statement on the activity and variations of the earth's magnetic field, in which consideration is given to the relation to solar activity through a day-by-day record, to secular change in the magnetic solar diurnal variation, to lunar diurnal variation in the earth's magnetism, and to magnetic and auroral activity. In the field of terrestrial electricity consideration is given to data derived from the College-Fairbanks Polar Station, to underlying factors controlling conductivity of the lower atmosphere, and to variation of small-ion production near the earth's surface. In the investigation of earth-currents, studies have been made from records in the observatories at Watheroo, Australia, and at Huancayo, Peru, and also from the Tucson observatory of the Coast and Geodetic Survey. The series of earth-current records at Watheroo now extends over eleven calendar years. For Huancayo the series extends over eight years, and for Tucson over three years. The range of observations extending over points widely separated on the earth has given extraordinary value to these studies, which could scarcely be undertaken by an institution less satisfactorily equipped with stations scattered over the earth and with knowledge of the earth problem.

Among the more important investigations in recent years covered in the reports are those which have to do with the detailed knowledge of ionization in the earth's

outer atmosphere obtained by methods employing the radio. These studies are important in many fields of investigation, not only for terrestrial magnetism but for advance in understanding of the problem of radio communication.

Concurrent with studies on the phenomena of nature as conducted with existing equipment, there has been continuous study of needs for new equipment through experimental and developmental work in the laboratory at Washington. A part of this research has involved the improvement of equipment utilized for research in atomic physics as related to magnetism, in which field the work of Doctors Tuve, Hafstad, and Dahl constitutes an especially significant contribution.

ASTRONOMICAL RESEARCH

An illustration of unbroken continuity in the work of the Institution is well shown in the field of astronomy, where conditions for work as determined by available instruments and by development of new theories have made necessary almost continuous variation in details of the program. And yet this present plan represents the evolutionary development of the program outlined when the work of the Institution was initiated in this field.

The Advisory Committee on Astronomy in its report of 1902 classified work in astronomy under two heads: (1) Investigations which involved the determination of the positions of the heavenly bodies and of their motions of every kind, real and apparent; (2) investigations on the physical and chemical constituents of celestial objects.

Out of representations of activities in such fields came establishment of the Department of Meridian Astrometry and a solar observatory at Mount Wilson, California. As

results of the first have come star catalogues preliminary to issue of a general catalogue covering positions of approximately 33,000 stars.

From the modest beginning of a solar telescope, the Snow telescope transferred from the Yerkes Observatory in 1904 by Dr. George E. Hale and set up on Mount Wilson, there has come the best equipped astronomical plant in the world, and the development of a staff of astronomers whose contribution to knowledge, particularly to that in the field of astrophysics, has been of incalculable value.

Director Adams' report on the work of the current year at Mount Wilson affords clear indication of how broad the front now is which represents the attack on the problems of astrophysical research which the Observatory is waging. Such items as the following illustrate the range which the program now covers:

Study of the sudden outburst of a star in the constellation Hercules—a study which has provided a mass of data which will yield a rich fund of information regarding stellar constitution, it is thought.

Study of an eclipsing variable star which has afforded unusual opportunity for obtaining fresh data on stellar atmospheres. Already the conclusion is suggested that present hypotheses concerning the matter are defective.

Further study of extra-galactic nebulae continues to yield data of great interest bearing upon the question of possible recessional velocities of stars as indicated by the red-shift of spectral lines.

Completion of the measurement of the velocity of light which closes a notable investigation begun 10 years ago by the late Albert A. Michelson. Final observations have

revealed variations in recorded values indicating the existence of disturbing influences of unknown value.

Continued observation of sun-spot activity and of other solar phenomena such as the general magnetic field of the sun.

The study of rare-earth spectra obtained through use of the electric furnace, providing data which are of importance in the interpretation of stellar spectra.

All these investigations and many more covered in Dr. Adams' report represent the present-day response to the observation made 34 years ago by the Advisory Committee on Astronomy that "the principal object of astrophysical research is to ascertain the physical and chemical constitution of the heavenly bodies, and to trace out and explain the successive stages in their evolution from nebulae."

Some of the most significant aspects of these researches at the Observatory are presented effectively in the form of statement used in the following quotations from Dr. Adams' annual report for 1935:

The outstanding astronomical phenomenon of the year has been the outburst of Nova Herculis. As to what happens when a nova suddenly appears we have little certain knowledge. The catastrophic nature of the occurrence is evident, and the course of some of the physical changes undergone by the star is gradually becoming clear; but the essential conditions preceding the outburst and the circumstance that sets it under way are still largely matters of speculation.

There is, however, perhaps more than a hint—although only of several possibilities—in Milne's recent studies of stellar constitution. These studies involve mathematical discussions of hypothetical models of stars consisting of spheres of gas. Definite distributions of pressure, density and temperature within the sphere follow from the assumed physical properties of the gas and the conditions affecting its radiation. Under certain circumstances a critical state occurs such that the gas sphere is no longer able to maintain its structure. The sphere collapses

into one of higher density and much smaller volume with an explosive development of radiation. Temperature and luminosity are enormously increased, and part of the gaseous material may be driven away into space as a nebulous shell. This theoretical approach to the problem is suggestive but hardly convincing, because it is by no means certain that the gas-sphere models really correspond to stars. Moreover, it does not seem to provide for the observational fact that novæ usually occur close to the galactic plane.

Observationally, what happens, and at this stage it is the observational data that require emphasis, is that an inconspicuous telescopic star, within a few hours or a few days at most, rises to a maximum of luminosity perhaps ten or twenty thousand times greater than that before the outburst, then, with many fluctuations in brightness, slowly declines until after weeks or months it is again inconspicuous and easily lost among other faint stars. Some months after the outburst, powerful telescopes may show the development of a disk or ring of nebulosity surrounding the star, which expands, apparently at a uniform rate.

The extraordinary transformations and the scale on which they occur render the phenomena of novæ among the most impressive known to the observer, and probably also among the most fruitful for the study of stellar constitution. For Nova Herculis, however, it is still too soon even to summarize the observational results. Several features undoubtedly will make its appearance noteworthy: first, the relatively slow approach to maximum, at least to the first maximum observed, thus permitting detailed study of early stages of its spectral development; second, the star's unusual brightness and slow decline from maximum, giving special opportunity for favorable observation; and, finally, its observation with the high dispersion of the coude spectrograph under conditions not hitherto available. The optical power of this instrument, together with the great number and the sharpness of the widely displaced absorption lines, will certainly yield a rich fund of information when the observations are discussed.

The fundamental part played by the distances of the stars in any study of the structure of our stellar system is obvious. The difficulties incident upon the accumulation of information on stellar distance are well known. The straight-forward trigonometric method, which utilizes the shift in the position of the earth from one side of its orbit to the

other, on the opposite side of the sun, can be applied only to the nearest stars. The introduction twenty years ago of the spectroscopic methods, which relieves to a large extent the restriction in distance, therefore afforded the means of an important advance. The first large accumulation of results, including 1646 stars, was published in 1920. Since then the method has been refined, the early results have been revised, and much additional material has been collected. The appearance of a second list comprising the spectroscopic parallaxes of 4179 stars, which has recently come from the press, marks the completion of another stage in an investigation which underlies or in some way bears upon every phase of the Observatory's work.

Even the spectroscopic method of determining stellar distance has, however, its limit of applicability. Very distant objects are, in general, so faint that their light is insufficient for spectroscopic analysis. In certain cases the observer may then have recourse to the remarkable relation between the cycle of light changes in a Cepheid variable and the intrinsic brightness of the star. The longer the period of light variation, the more luminous the star. By determining the period, the intrinsic brightness can be found; and then, just as in the spectroscopic method, comparison with the star's apparent brightness gives its distance. The use of Cepheid variables in determining the distance of globular clusters and extra-galactic nebulae has done much to center interest upon this important class of stars. In addition, they have an interest of their own, for their changes in brightness, caused apparently by pulsations of the gaseous mass of the star, set them in a position of importance in any study of the internal constitution of stars. Finally, not only can their distances be determined with accuracy; they are themselves objects situated at very great distances, and hence in a key position for a study of such questions as the absorption of light in space and the rotation of the galaxy. A program of spectroscopic observation of Cepheids pursued for many years has now been practically finished, and some of these questions are now under discussion.

Occasional sun-spots belonging to the old cycle were still to be seen in low latitudes during the year 1934. The sharp increase in the numbers appearing in high latitudes from 2 in 1933 to 52 in 1934 indicated, however, that the new cycle was well under way; and it now seems clear that the intensity of the sun's ultra-violet radiation has also passed a minimum. The magnetic polarities of spots maintain their customary

regularity in the distribution of the algebraic sign of the field and firmly establish the complete reversal of signs in the new cycle relative to the old announced a year ago. Study of the frequencies of dark hydrogen flocculi suggests that they follow the main fluctuations in the earth's magnetic field more closely than do those of the sun-spot curve. The intensities of the bright hydrogen associated with spot groups show no correlation with the sun-spot cycle. Continued investigation of the sun's rotation, with special attention to systematic errors produced by scattered light, increases the rotational values obtained since 1914 by about 4 per cent and makes the Mount Wilson measures as a whole much more consistent. Further improvements in sensitizers for photographic plates have made it possible to push the limit of spectroscopic observation on the sun another thousand angstrom units into the infra-red. Investigations in the infra-red region are still largely of such fundamental matters as the scale of wave-lengths and the intensities of lines. As a rich source of astrophysical information, the field is still almost untouched.

Equally important with distances as fundamental data are the apparent magnitudes of the stars. In fact the magnitude of a star must be known before spectroscopic criteria or Cepheid variability can be used to find its distance. The determination of suitable standards of brightness, well distributed in the sky, is one of the essential steps in supplying the photometric data needed to obtain the distances not only of stars but also of globular clusters and extra-galactic nebulae. Much progress in standardization is now being made, partly of the faintest stars observable with the 100-inch telescope and partly of stars brighter than the twelfth magnitude, whose brightness is still imperfectly known in spite of the fact that they are within easy reach of small telescopes.

Directly associated with measurements of brightness are measurements of color, which have a significant bearing on the absorption of light by interstellar clouds of dust and gas. Measurements of this kind made with the photoelectric cell are proving of exceptional value. Observed in this manner, B-type stars, globular clusters and extragalactic nebulae all reveal the stratum of absorbing material close to the galactic plane and a dependence of color on position which denotes increasing absorption as the direction of the center of the stellar system is approached.

The studies of extra-galactic nebulae continue to bring forth results of outstanding interest. Red-shifts of spectral lines corresponding to recessional velocities of 24,000 and 39,000 km. per second have been

confirmed, and for an object in a faint cluster of nebulae in Ursa Major a value of 42,000 km. per second, from a single spectrogram, however, is now available. The evaluation of the influence of the red-shift on the apparent magnitudes of these remote objects has already become a pressing matter, because any calculation of the distribution of nebulae in space depends on the values of the magnitudes freed from this disturbance. The amount of the correction, however, will be determined by the physical interpretation of the red-shift itself; and although we know only motion in the line of sight as a competent explanation, it would be incautious on present evidence to assert that motion is certainly the correct interpretation.

An intensive study of red-shifts, regarded as the consequence of motion, for 30 nebulae in the Virgo Cluster has led to a number of striking conclusions, among them a value for the average mass of the individual nebulae which is a hundred times that derived from isolated non-cluster nebulae. These results are not necessarily inconsistent; but if the high value for the cluster nebulae is of the right order, it probably indicates the existence of a great amount of inter-nebular material within the cluster. The question is of great importance for cosmological investigations.

The extraordinary advance made in theoretical spectroscopy in recent years has put heavy demands on the physical laboratory. To utilize the full advantage of these gains on the theoretical side, they must be made applicable to definite astrophysical problems. For this purpose term analyses of the spectra of the different elements must be available. At this point laboratory data on the positions, intensities and temperature characteristics of spectrum lines become an essential. For some years the complicated spectra of the rare-earths have been under observation in the laboratory of the observatory. The magnitude of the task is suggested by the numbers of the lines studied and classified—for example, 1200 for europium, 3000 for gadolinium, and nearly 4500 for samarium. The stronger lines of the ionized spectra of all three elements appear in the sun, but not the neutral lines in accordance with the usual behavior of the rare-earths. The experimental work indicates that the phenomenon is one of abundance. Low vapor density affords so few opportunities for recombination of electrons with ionized atoms that neutral lines do not appear. The inference is, therefore, that these elements are scarce in the sun, as on the earth.

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The publication of the final results of the measurement of the velocity of light closes an investigation started ten years ago by the late Albert A. Michelson of the University of Chicago. Four series of measures, each including several hundred observations made with a mile-long vacuum pipe line during intervals of 2 to 5 months, give mean values which show an average deviation of 3.5 km. per second and a final mean of 299,774 km. per second. The internal agreement points toward an uncertainty of 1 or 2 km. per second in the final result. The value found from the measures made in 1926 (a few of low weight in 1925) over the open-air path of 22 miles between Mount Wilson and Mount San Antonio was 22 km. per second higher. The cause of this disagreement is not known. The observing conditions in the two cases were, however, entirely different; in one, a relatively short path of 8 or 10 miles, obtained by multiple reflections within the pipe line under a pressure of only a few millimeters of mercury; in the other, an air path of 45 miles that twice traversed a wide deep canyon. However we rate the influence of this difference in conditions, a striking feature of the recent measures should be noted. Even with all possible care in the manipulation of the apparatus, abnormal values of the observed velocity, sometimes high and sometimes low, persisted at times during days or even weeks, thus indicating the existence of disturbing influences of unknown origin. It is possible that the value of the velocity from the 1926 measures is systematically affected by error of this kind. The two-year interval covered by the four recent series and the general accordance of their respective results suggest, on the other hand, that the influence of any such error on the adopted mean velocity must be relatively small.

The proposal of the Advisory Committee on Astronomy to secure much needed data concerning positions of the stars led to organization of a large project in this field which was set up in 1907 under the direction of Dr. Lewis Boss, as the Department of Meridian Astrometry.

**Mapping and
Cataloguing
of Star
Positions**

The proposed work, covering stars down to the ninth magnitude, was conducted under Dr. Lewis Boss until his death in 1912 when it was taken over by Mr. Benjamin

Boss, and has been continued with an able staff up to the present time.

Observation and compilation by this Department have given us already catalogues establishing the positions, and with this the possibility of study of motions appearing under the titles of "Preliminary General Catalogue of 6,188 Stars for the Epoch 1900," "Albany Zone Catalogues for the Epoch 1900," "San Luis Catalogue of 15,333 Stars for the Epoch 1910," and "Albany Catalogue of 20,811 Stars for the Epoch 1910." The Department is now bringing to completion the "General Catalogue," covering approximately 33,000 stars.

The significance of this material is much greater today than could perhaps have been foreseen at the time the work was initiated, and the data secured will go into immediate use over the world in a wide variety of astronomical studies concerning structure and movement in the stellar system within which we reside.

The work of this Department, which has been nearing completion in recent years, reached the stage of practical summing up of the results in the year 1935. Manuscript of the first part of the General Catalogue is now in hand and publication will proceed as rapidly as possible. Final checking and preparation of the last portion of the manuscript for publication will continue to completion of the publication program in 1936.

The Committee on Surface Features of the Moon, established in 1925 for the purpose of examining problems relating to physical features of the moon from all feasible points of view, illustrates in an extremely interesting way the possibilities of study by groups of investigators approaching a problem

**Studies of
the Moon
Committee**

from different positions, and with quite different objectives. The work of this Committee under the chairmanship of Dr. F. E. Wright of the Geophysical Laboratory includes the researches of the astronomer, the volcanologist, the physiographer, the physicist, and the mathematician, and represents the coöperation of many institutions.

The continuing study of this Committee has not only given us a new view regarding the nature of the moon, its composition, and its structure, but it has presented for comparative investigations a group of phenomena by use of which the surface of our own earth may be examined to advantage. There is perhaps no object in astronomy which has more persistently and continuously absorbed the interest of investigators than the moon, and yet, after all that has been done in past years, with the method of attack which is now being used, the results derived are of unusual significance.

One may look upon the contribution in this research as illustrating in an exceptional way the advance of science made possible by new basic theories, by new instruments, such as the 100-inch telescope, and by new methods of coöperation as is represented by organization of the Moon Committee.

COSMIC-RAY RESEARCH

Although the Institution has not itself organized a special project for study of the fascinating problems in cosmic-ray research, it has been possible to give aid in furtherance of researches for which financial support has been furnished by the Carnegie Corporation of New York.

In order to select the projects, and to bring about such coöperation as might reduce the total expense in effort and money, a committee was organized consisting of Dr. John A. Fleming, Dr. Walter S. Adams, and Dr. F. E. Wright.

This committee has functioned during the past two years in organizing a program for cosmic-ray research, in co-operation with leading investigators, and in furnishing such special facilities as could be made available through equipment and stations of the Institution.

As leading up to the present program of cosmic-ray research, the Institution had in earlier years made possible significant advances of knowledge through use of data collected by members of its staff. Especially important was the contribution of the Department of Terrestrial Magnetism through data assembled by Mr. O. H. Gish on the last voyage of the *Carnegie*.

Along with other cosmic-ray studies under way during the past year, three groups of investigations aided by the Institution have been especially important. These are the researches of Dr. Robert A. Millikan and associates, of California Institute of Technology; of Dr. A. H. Compton, of the University of Chicago; and of Dr. Thomas H. Johnson, of Bartol Research Foundation. The contributions made by Dr. Millikan, following upon many years of intensive investigation of this subject, have involved an extremely interesting variety of studies, which began in the laboratory with theoretical research and construction of new and better types of instruments, and extended to wide study of the effect of cosmic rays geographically, both with reference to latitude and to longitude, and with respect to upper and lower levels of the atmosphere. The seven projects upon which specific report has been made by Dr. Millikan include:

(1) Measurements in connection with the Kepner-Stevens stratosphere flight with reference to precise shape of the ionization-altitude curve made with a self-recording Neher unshielded electroscope.

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(2) Measurements made with Ncher recording electrosopes in three different airplane flights in Peru up to a maximum altitude of 28,000 feet.

(3) Measurements on the equatorial longitude-effect in cosmic rays. These measurements were made by self-recording Ncher electrosopes which were sent on world-encircling cruises covering a wide range of territory; also cruises from Los Angeles to Sydney and return and up to the west coast of South America through the Panama Canal to Liverpool and returning through the Atlantic Ocean around Cape Horn to Mollendo. These explorations confirmed the results announced earlier concerning the existence and magnitude of the equatorial longitude effect and making possible a much more reliable survey of variation over the earth's surface of cosmic-ray sea-level intensities.

(4) In the prolonged and accurate determination of the distribution of cosmic-ray energies as given in Pasadena by the vertical cloud-chamber method of Millikan and Anderson.

(5) Cosmic-ray counting studies which have improved considerably the resolving power of a cosmic-ray counting system, and making possible a more accurate study of the possible influence of celestial objects upon cosmic-ray intensities.

(6) The development of a new and improved technique for measuring cosmic-ray ionization in the stratosphere.

(7) Separation of cosmic-ray effects at the earth's surface from local radioactive effects.

An important group of scientific papers has recorded the results of this work as rapidly as possible.

The work of Dr. Compton has been directed, first of all, to a cosmic-ray survey with relation to both magnetic latitude and longitude effects, and with reference to the influence upon cosmic rays by the earth's magnetic field. There has been also an analysis of the composition of cosmic rays and a study of variation of intensities. Studies have also been made on the apparent effect due to rotation of our galactic system, or Milky Way, and attention is directed to the fact that if existence of effects

discussed is confirmed, the origin of the cosmic rays must be beyond the galaxy itself. It is also noted that these studies have relation to a method of observing the important astronomical phenomenon of galactic rotation.

The researches of Dr. Thomas H. Johnson include a survey of directional distribution of cosmic radiation with reference to the determination of the east-west asymmetry at two high elevations in Peru, at sea-level in Panama, and in Pennsylvania. Measurements in Mexico of an exploratory nature have also been made. For the purpose of more intensive survey an automatic interdirectional cosmic-ray intensity comparator was developed, and with it extensive measurements were obtained at many stations, including western United States, Pennsylvania, and Mexico. These studies have led to consideration of the analysis of variation of asymmetry with atmospheric path length and its significance with reference to absorption of corpuscular intensity.

HYDRODYNAMICS OF THE ATMOSPHERE

In some respects related to certain aspects of investigations in the Department of Terrestrial Magnetism, and in another direction intimately connected with studies of Mount Wilson Observatory on the atmosphere of the sun are the investigations of Dr. V. Bjerknes, of Oslo, Norway, on hydrodynamics of the atmosphere. These researches have been continued from 1906 to the present time with the aid and coöperation of the Institution. The critical mathematical and physical studies of Dr. Bjerknes on the hydrodynamics and thermodynamics of the atmosphere have developed into investigations of world importance and of basic value in consideration of

modern problems in meteorology. The publications by Dr. Bjerknes and his group of associates constitute an epoch-making contribution to knowledge, with reference basically to hydrodynamics, and relating in their application to studies of atmospheres both on the earth and upon the sun.

The latest studies by Dr. Bjerknes have concerned the practical application of the data secured to facts and theories of importance in meteorology and hydrography. The data leading up to present application are represented in the Year Books of the Institution extending from Volume 5, 1906, to Volume 34, 1935.

Recent studies by Dr. Bjerknes and his associates have given us a further step in the study of formation of atmospheric fronts. Dr. Bjerknes calls attention to the fact that when the subject is treated completely "one must take into consideration simultaneously the field of motion and the field of that property (for instance, temperature) which is to be investigated. As long as both fields are linear, no actual front formation takes place; therefore at least one of the fields must be supposed to be not-linear. Dr. Petterssen takes cognizance of this and deduces results which will be useful in practical weather forecasting. This, and the general review which Dr. Petterssen gives of the singularities which can occur in the linear field, will be incorporated in the new edition of 'Kinematics.' "

Dr. Bjerknes reports further on some of the results of his recent work as follows:

Dr. Godske has sent to press (Geofysiske Publikationer, Oslo) a paper: "A Simplified Treatment of Some Fluid Oscillations." As all atmospheric disturbances, even those developing into cyclones, must start as some kind of small oscillations or waves, it is very important to

arrive at easy methods of dealing mathematically with this class of motions. In cases in which it can be applied, the method developed by Dr. Godske represents a very effective simplification of the much more laborious "classical" methods used in our work "Hydrodynamique Physique" (see Year Books Nos. 31 and 32).

Professor Solberg has continued his theoretical investigations on wave-motions on a rotating earth. The aim of the investigations, which have been referred to in the last two Year Books, is to improve the Laplacean theory of oceanic and atmospheric tides, and to develop a complete theory of cyclones as waves in the atmospheric surfaces of discontinuity. The mathematical theories are completed and Solberg has started the numerical calculation of his formulæ. The results hitherto obtained show that the Laplacean free oscillations give a good approximation to reality as long as the period is short, but as soon as the period approaches the critical value of 12 hours, the Laplacean theory ceases to be valid. And for still greater periods the motion becomes totally different from those expected from the Laplacean theory.

Professor J. Bjerknes has recently sent in for publication (Geofysiske Publikationer, Oslo) a paper: "Investigations of Selected European Cyclones by means of Serial Ascents. Case 3: December 30-31, 1930." For the plan of these investigations see Year Book No. 29. The study has been continued with the participation of an increasing number of cooperating aerological observatories, the aim being to find, by real ascents in sufficient number, the true structure of typical cyclones. The results, in general, confirm what had been expected from the Polar Front Theory, but it is still too early to formulate final conclusions. "Case 4" was February 15-17, 1935, when 15 aerological observatories cooperated upon a telegraphic start signal from Bergen.

The telegraphic Weather Chart is to the meteorologist what the telescope is to the astronomer or the microscope to the biologist; it is the instrument through which he observes the phenomenon that he is studying. And as every step in the construction of the telescope or microscope advances astronomy or biology, so every improvement of the telegraphic weather service advances both practical forecasting and scientific meteorology. But as weather telegraphy depends upon international conventions, reform is exceedingly difficult.

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After the formation of the Forecasting Central at Bergen, Norway, in 1918, the Norwegian representatives in the international committees and commissions have worked energetically for improvements, and now that the "Bergen Methods" are more liberally introduced in the meteorological service of an increasing number of countries, this has much facilitated the system of weather telegraphy.

Director Hesselberg, who in former years worked under the grant from the Carnegie Institution, and Dr. Bergeron have been most active in these researches. Bergeron has elaborated a proposal to "Comments on the new Codes for Synoptic Weather Information adopted in Copenhagen, 1929." The aim of these "Comments" is to get the greatest possible uniformity and avoid confusion and errors in the observing, coding, decoding and forecasting work.

STUDY OF MAJOR CLIMATIC VARIATIONS

Out of a study of ecological influences there arose in 1915 a research on climatic variations conducted by Dr. A. E. Douglass of the University of Arizona through the medium of his study of tree-ring variation. These investigations have continued uninterruptedly and with increasing importance up to the present time. Early in the past year arrangement was made by which the work of Dr. Douglass could be concentrated upon his study of climatic changes, or of cycles, which Dr. Douglass believed to be represented in the variation of tree-ring growth. If, as is assumed by Dr. Douglass, the growth of trees through addition of woody rings of varying types illustrates changes of climate, and if these climatic variations are of cyclic type, information secured from the trees as to the nature of the cycles, or the sources of the influence bringing about these changes, would be of enormous significance to the whole world for all time.

In the recently planned organization of studies of Dr. Douglass on climatic changes, the University of Arizona

has given its coöperation through permitting Dr. Douglass to continue his work at the University, and to maintain his connection with that institution. The Carnegie Institution has in large measure taken over the expense of the investigation, including assistance to the extent which might be required and necessary equipment for these studies. In extension of the work, the chronological record represented in tree rings of beams in ancient buildings of the southwest has been of great significance, as there is furnished here a record not only of human life, but of variation in tree growth, which Dr. Douglass believes to represent changes in factors of climate. The record secured by Dr. Douglass, extending back nearly two thousand years, gives unusual opportunity for study of possible cyclic changes.

Investigations by Dr. Douglass have been supplemented in various directions, and more recently by the work of Dr. Ernst Antevs, who, in connection with studies on the beginnings of human history in the southwest, has made an investigation of climatic changes which may be illustrated in the various types of deposits by lakes, rivers, and glaciers.

In order to give the best possible opportunity for study of data bearing upon climatic changes and their possible cyclic nature, a series of conferences was arranged in the past year for discussion of these questions by leading students in this field. Meetings were held at the Laboratory of Plant Biology at Palo Alto, at Mount Wilson Observatory, at the University of Arizona, and in Washington. These discussions brought together Dr. A. E. Douglass; Dr. I. W. Bailey, student of the biological aspect of tree growth; Dr. R. W. Chaney, palæobotanist; Dr. J. Bar-

tels of Germany, a leading student of cycle problems; Dr. S. Chapman of England, a distinguished student of astronomical and physical problems concerning cycles; Dr. Walter S. Adams, Dr. F. H. Seares, and Dr. Seth B. Nicholson of Mount Wilson Observatory; Dr. Dinsmore Alter, a distinguished investigator of cycle problems in weather and rainfall; Dr. Frederic E. Clements of the Division of Plant Biology; and Dr. F. E. Wright, Chairman of the Institution committee on interdepartmental problems in the physical sciences. The results of these discussions will have great importance in bringing to clear understanding critical problems under study by Dr. Douglass.

In one direction the investigations by Dr. Douglass are connected in an interesting way with those of Dr. Bjerknes concerned with study of the hydrodynamics of the atmosphere. If, as Dr. Douglass believes, a series of climatic changes, or shifts, or cycles is represented in the story of the earth, a basic element may be furnished which will contribute to our understanding of certain aspects of climatic change. On the other hand, the work of Dr. Bjerknes, concerned with the normal adjustments which take place within the atmosphere of the earth, furnishes data which interpret changes brought about by factors presumably quite different from those discussed by Dr. Douglass.

PLANT BIOLOGY

The Division of Plant Biology, like that devoted to biology of animal forms, passed through a stage representing first a group of wholly separate investigations, each directed toward a specific and important objective,

covering many regions of plant research from classification of types, through problems of structure, physiology, genetics, ecology to palæobotany. These activities were widely scattered geographically, and in a number of instances the points of view were so different as almost to constitute opposite poles of thought. The contributions coming out of these different researches have, however, laid the foundations necessary for new studies on many of the ultimate values in plant biology.

With the formation of the Division of Plant Biology in 1928 the several groups have come into extremely helpful relation to each other, and there has begun again, but in another way, the contrast of points of view represented by different approaches to comparable materials. The types of problems have in some respects been similar to those undertaken in animal biology, though we have still to learn whether, basically, plant and animal biology are wholly similar, or whether the modes of procedure in nature will be found sufficiently different to give us through this variation a better understanding of the real significance of life processes.

In that phase of development in plant research which began with re-statement of the problem in a Division of Plant Biology there developed in the Institution new opportunities for attack upon certain questions which are fundamental in biology. Discussion of some of these problems is presented effectively in the report for 1935 by Dr. Spoehr, Chairman of the Division, as follows:

For a number of years a major effort of the Division of Plant Biology has been directed to the study of the influence of climatic environment on the life and development of living organisms, particularly of plants. These investigations have been carried out by different groups, or sec-

tions, of the Division, which have attacked special features of the general problem, with different types of material, in different sections of Western United States, and with varying viewpoints and modes of approach. The expression of climate in terms of vegetation and plant societies, the effects of changes in the climatic complex, the possible periodicities of climatic changes, and the evidences of climatic changes throughout long periods of time are of fundamental significance for an understanding of the forms of plant life as these exist today. Conclusions regarding these phenomena may well contribute to a solution of the more immediate problems of climate in its bearing on agriculture and forestry. Many of these investigations of necessity involve long periods of observation and experiment, and it is largely through cumulative experience under a diversity of conditions that results of value can be obtained. Several of these projects are now being brought to a definite focus in an effort to give expression to general conclusions.

In 1922 an extensive experiment was undertaken by the late Dr. H. M. Hall to determine the extent to which taxonomic characters are modifiable through habitat factors. These experiments have been continued and somewhat extended since the death of Dr. Hall. The elaborate data resulting from these transplant experiments have been summarized through the year 1932, and the more general facts, which thus become evident, are being assembled for publication.

During the year an extended botanical exploration was carried out in Baja California by an expedition from the Desert Laboratory. The extreme aridity, which characterizes this peninsula in spite of the proximity of large bodies of water, and the many species of plants and types of vegetation, which are peculiar to it, make the study of this region an important part of the investigation of the great Sonoran Desert, which for some time has been a major program of the Desert Laboratory. Whereas on previous visits there had been no rain in several years, the year 1935, because of the unusually heavy rains, presented the most favorable opportunity in twelve years for the study of the vegetation of this region.

The penetration into the composition of any living organism or its processes has almost invariably revealed a vastly more complex situation than was expected at the outset. To this experience the study of the photosynthetic apparatus of plants is no exception. While the general outline of the chemistry of the green pigments, which are essential for

photosynthesis, has been well established, the chemical structure and properties of the less obvious yellow pigments of leaves is still in progress of elucidation. The task has been greatly complicated by the fact that these latter components of the photosynthetic apparatus are far more numerous than was at first supposed, and the separation of the individuals has presented many difficulties. The necessity of contriving means of separating these individuals has, on the other hand, also led to a better understanding of their properties, so that this more intimate knowledge is serving as the basis for the development of theories concerning the rôle of these substances in the photosynthetic process.

ANIMAL BIOLOGY

Following the ideas of Mr. Carnegie regarding the furnishing of opportunity for investigation of scientific problems of special importance wherever the work might best be conducted, and by such organization as may seem most effective, but always through the medium of especially competent individuals, work in animal biology first developed in the Institution as a number of separate projects covering a wide range of subjects. The establishing of the Department of Marine Biology under Dr. Mayor in 1906 with new and relatively effective equipment, the founding of the Department of Experimental Evolution at Cold Spring Harbor in 1906 under Dr. Davenport, and the setting up of the Embryological Laboratory in Baltimore in 1914 under Dr. Mall represented three types of research in which careful organization of a somewhat complicated program was essential for success. Contribution to the work of Dr. T. H. Morgan for aid in his epoch-making studies on the mechanism of heredity at Columbia University illustrated another type of activity, through the medium of a distinguished investigator maintaining his relation to the academic program of a university.

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The gradual change from widely spread groups, each with its particular contacts, to the form of the Division of Animal Biology now in existence presents an extremely instructive story concerning development of mutual relations which seemed important without reference to organization, and ultimately resulted in formation of a group which may, when desired, act as a unit. The following brief statement regarding progress in this organization given by Dr. George L. Streeter, Chairman of the Division, is taken from the annual report of Dr. Streeter as presented in the Year Book:

Since its incorporation in 1904 there have grown up within the Institution various programs and laboratories for biological research, concerned primarily with the physiology, anatomy, embryology, evolution, and heredity of animals. The individual projects were in each case located where it seemed they could be best conducted. In course of time it has been found that in their development these researches tend to overlap and bear one on another, and this has led to increasingly frequent consultation and exchange of facilities between the individuals of the different groups and cooperative endeavors have been found mutually advantageous.

The community of interest that has thus arisen was administratively recognized at the beginning of the present year by the formal establishment of a Division of Animal Biology. Under it are grouped the Nutrition Laboratory located in Boston, the Department of Genetics including the Station for Experimental Evolution and Eugenics Record Office both located at Cold Spring Harbor, the Department of Embryology in Baltimore, and the Tortugas Laboratory on Loggerhead Key, Florida.

There may be value in further comment on the nature and function of the Division of Animal Biology, since it is clear that the conferences developing out of interrelations of these groups have not only been significant for

each of the smaller bodies of workers, by bringing the point of view of other sections of the Division, but the conferences have tended also to outline new problems of a comprehensive type, which it would not be easy to define excepting through focusing the thought of a number of workers in the areas that are common to several fields of investigation. It is also to be noted that the fact of organization of the Division, with the increasing of facilities for exchange of ideas and for coöperative research among the workers of the staff, has made easier certain aspects of coöperation with other divisions of the Institution, as also with workers in other institutions.

As seems almost inevitably to occur in research work, investigations developed in the broader fields of animal biology have shifted a considerable distance from the projects as originally defined. So it had happened that while the Department of Embryology in the Division of Animal Biology is still devoted to history of the individual in the stages from egg to birth, correlated investigations such as those of Dr. Hartman and his colleagues on the meaning of endocrines in reproduction have naturally and properly tended to become relatively important, until their significance becomes so marked that it brings the concentrated attention of many investigators. In the same way, in the Department of Genetics, the work of Dr. Riddle has moved over to intensive study of certain aspects of endocrines until there is developed here also a research of such value that it tends naturally to overshadow for the time being other phases of this particular program. It thus comes about that both in genetics and in embryology there is concentration of interest upon

certain aspects of the endocrine problem, so that the two groups are brought into close relation.

Considered broadly, activities within the Division of Animal Biology, with emphasis first upon one problem and then upon another, have come to cover many of the most critical biological questions. They begin with the development of the cell and the problems of inheritance. In the Department of Embryology, in addition to consideration of qualities received through inheritance, there are involved the influences exerted upon the individual through the stages which we describe as the embryo. In the Nutrition Laboratory emphasis is placed upon the factors which in large measure control development of the individual with relation to his utilization of energy and the source of this energy. In the section of work devoted to eugenics there has been consideration of problems of growth in terms of both genetic limitation and environmental circumstances. This is, of course, true both in early stages of human beings and in those of other animals. One finds, then, that in this division devoted to a wide variety of specific researches, while the desired result can be obtained in each case only by the most intensive concentration of interest and effort, the final result is often dependent upon relation to other investigations representing somewhat different points of view.

The contributions of Animal Biology in its several sections represented by the Nutrition Laboratory in Boston, the Department of Genetics including eugenics, the Department of Embryology, and the Tortugas Laboratory may be considered with reference to researches in the past year through the following quotations from the an-

nual report for the year prepared by Dr. George L. Streeter, Chairman of the Division:

In reporting the obtaining of 10-day macaque ovum last year, emphasis was laid on its embryological importance and the fact that it extends our vision of the mechanism of development into the 24-hour period, preceding any hitherto known primate embryo. If that was important last year, there is this year to be reported something still more significant, namely the 9-day macaque ovum, another 24 hours earlier. Two excellently preserved specimens representing this stage have been obtained, one a little more advanced than the other. The younger of these is a blastocyst which was still unattached in the uterine cavity and the other was just beginning to fasten itself to the uterine wall. Of all the various stages we could have wished, the latter is the one we would have preferred. It should again be pointed out that obtaining this material is not mere chance but the result of planning, experience and expertness in every step of the procedure. It is the result of good management of the monkey colony and thorough acquaintance with the physiological processes of the animals concerned, and it is equally the result of cunning operative technique followed by the technical requisites for handling, preserving, photographing and sectioning these minute objects. With that much accomplished, any embryologist can now place the material under the microscope and clearly observe in serial sections the structure of the egg at this early period, and he will find, as we have found, many quite unexpected things.

Increased activity in the study of insect chromosomes has been given a new impetus by the realization of the opportunities offered by the giant chromosomes of the salivary glands. It has now become possible to correlate deficiencies identified by genetic methods, necessarily speculative, with visible structural changes in these large chromosomes. This material should make it possible to carry the analysis of the action of the gene on the organism much further than can be done by genetic studies alone. It has been found in some instances that certain transverse bands are absent in specific deficiencies, and in this way it is hoped that a complete chromosome map of the genes can be constructed. On the other hand careful cytological studies of the chromosomes are being made in different insect species which have already yielded impor-

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tant features regarding the basic structure of the chromosome. The first task has been to distinguish to what extent the appearances seen are in the nature of artifacts and to what extent they are actual structures invariably present. By use of photographic technique, evidences on these points have been obtained. Study of deficiencies has been continued by the regular genetic methods, including their experimental production by x-rays.

Investigations in plant genetics have been continued with various species of *Datura*, in which chromosomal differences between species are analyzed through hybridization experiments. Prime types are recognized within individual species and they differ genetically one from another apparently by shifting of ends of chromosomes through segmental interchange, just such differences as are found between species. An important factor in crossability, in which chromosomal hypotheses do not have to be resorted to, has been found to be the ability of pollen of one species to grow in the style of the other, and this in turn depends on the rate of pollen-tube growth and on the length of the style. Mutations have been produced by temperature and moisture conditions injurious to the seed. In this material new characters have been recognized which can be used in further breeding experiments and will aid in the location of genes in their proper chromosome.

The studies on Leukemia in mice have led to problems of wide significance, such as the nature of malignancy itself. In studies carried on in the Department of Embryology, evidence has led to the belief that malignant cells are permanently and specifically altered ones. This appears to be true also for mouse leukemia. It thus involves an understanding of the relation of genes and cytoplasm in the control of development and heredity. The interaction of the leukemic cells and the hosts in which they are growing is also of importance and has led to the perfection of a method of immunization against leukemia. Immunization can now be established not only by the graded injection of leukemic cells but also can be induced by grafts of normal embryonic tissue, a much safer means. In carrying out these latter experiments, the discovery was made that success or failure depended on the genetic constitution of the tissue used, and this appears to offer a most favorable approach to the testing of the rôle of genes in controlling the differentiation of leu-

kemic cells. In further studies on the nature of the immunizing process, it has developed that mice immunized to inoculations of virulent leukemic cells nevertheless acquire spontaneous leukemia and die from it with the same frequency characteristic for the strain. In other words, different properties are required to kill leukemic cells that occur spontaneously and the highly malignant cells that are inoculated experimentally.

In the studies on endocrinology, an outstanding result of the year is a demonstration of the dependence of the maternal instinct (rats) upon the hormone, prolactin. Though the mechanism by which the hormone affects nerve or brain function is wholly unexplored, this is an important instance of the participation of a somatic or extra-neural agent in the development of a normal element of the mind.

During the twelve weeks of its operation, the Marine Laboratory at Tortugas was visited by fifteen investigators. In addition to a continuation of the survey of fishes of that region, their researches included observations on new species of ciliates; regeneration in crustaceans, tunicates and annelids; control of color patterns of coral-reef fishes; cytology of the hypophysis of the shark; correlation between the morphology of the pectoral fin of fishes with its variation in function; effect of variation in light intensity on cytoplasmic structure in the simpler marine organisms; effect of temperature and light on inherent electric potential of *Valonia*; effect of amino acids, tissue extracts and salts of heavy metals on the acceleration of metamorphosis of ascidian larvæ; intracellular determination of hydrogen-ion concentration in ova of marine invertebrates; and photodynamic properties of vital dyes. The last-mentioned study is closely allied to the studies carried on in the embryological laboratory on photofluorescein, noted above.

HISTORICAL RESEARCH

The researches in history of the Carnegie Institution originated in several fields of thought and with different modes of approach to the study of historical sequence. Following organization of historical research under directorship of Professor Andrew C. McLaughlin in 1903,

the Department of Historical Research was established in 1905 under the leadership of Dr. J. F. Jameson. These studies initiated a series of extremely careful investigations into such sources of the history of the United States as are essential for the development of an accurate and dependable record. Out of these researches in varied sources of material have grown important contributions by Dr. E. C. Burnett covering "The Letters of Members of the Continental Congress"; by Miss Elizabeth Donnan on "Documents Illustrative of the History of the Slave Trade to America"; by Mrs. Helen C. Catterall on "Judicial Cases concerning American Slavery and the Negro"; by Dr. John S. Bassett on "Correspondence of Andrew Jackson"; and by Dr. Charles O. Paullin in the "Atlas of the Historical Geography of the United States."

Problems of human history representing the earlier stages in development of the race were initiated independently, and largely through the studies of Dr. S. G. Morley, on certain aspects of Maya history of Middle America. These investigations broadened to cover the whole story of the Maya, including not only archæology in the more limited sense, but with this a knowledge of the present-day Maya, together with an account of their environment and their accomplishment in the sense of culture and art along with social and governmental organization.

The history of science, initiated through support of the outstanding work of Dr. George Sarton, has centered largely upon the production of Dr. Sarton's great work on "Introduction to the History of Science." One of the significant contributions from research on the history of a subject such as science, this work concerns itself with the evolution of science and the process of its building. The

work done by Dr. Sarton gives exceptional material for evaluation of science as an influence in development of the basic elements in civilization.

The combination of interests represented in history brought together in one division has furnished the opportunity to study history as science, art, culture, sociology, and government in all phases, with application of the scientific principle first to the gathering of materials and, second, to interpretation of the data secured. Whatever be our views concerning the extent to which the laws of natural science may be applied in the study of man, there can be no doubt that the basic method of science, involving rigorous scrutiny of facts, and utilization of principles of logic in the interpretation of these facts, is necessary in research upon any problem to which the human mind may give itself. Nor can there be question regarding the desirability of attempting to discover the extent to which human conduct lends itself to examination through search for modes of procedure known in science as laws. It may be that human history will not show the degree of reliability or predictability which characterizes the physical and biological sciences. However, there can be no question but that, from certain angles, human history may be looked upon as itself not merely an experience but an experiment, the values of which should be useful for mankind in attempting to determine paths which it may to advantage follow in the future.

The contributions made through the Division of Historical Research, including all aspects of its work in recent years, is one of the outstanding achievements of the Institution in drawing together scientific and cultural or human interests. The method used should be valuable

both in bringing science into the study of human culture and in using human culture to illuminate in some measure materials of science which left to themselves might tend to become so rigid as to be unnatural.

The point of view of those engaged in the study of historical research in the past year, and their accomplishment, is stated in an interesting form in the annual report of Dr. A. V. Kidder, Chairman of the Division.

To the panscientific survey which the Section is carrying on in the Maya field there have been added, during the past year, two important new activities, the Copan Projects and the Maize Survey.

The Copan Project, under direction of Mr. Stromsvik, is a joint undertaking of the Government of Honduras and Carnegie Institution, the Institution's share of the expense being covered by a grant from Carnegie Corporation. At Copan, one of the greatest centers of Old Empire culture, the Institution is continuing its effort to conserve and make available for scientific study and lay observation outstanding examples of the architectural and sculptural art of the ancient Maya. The repair of the Temples at Chichen Itza was done for the same purpose, as was the mending and re-erection, in 1934, of the stelæ at Quirigua. Copan fits well into this program, for its sculptures are not only among the finest ever produced by the Maya, but were also in urgent need of attention, many of them lying so broken and scattered by earthquakes and the impact of falling trees that their beauty could not be appreciated, nor could it be hoped that their fragments would long survive the destructive effects of brush fires and exposure to the weather. Results of Mr. Stromsvik's very effective work during the past season are presented in a later section. Here should most warmly be acknowledged the invaluable cooperation of the Honduranian Government, which has provided all labor and free transportation from the border of all equipment and supplies. Furthermore, the Minister of Education, Dr. J. Rodriguez, and President Carias' personal representative, Sr. Carlos Izaguirre, repeatedly visited Copan during the season to confer with Mr. Stromsvik and to see that everything was being done to facilitate the work.

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The second new development was establishment of cooperation with the United States Department of Agriculture. Through the good offices of Secretary Wallace and of Mr. Knowles A. Ryerson and Mr. Frederick D. Richey, former and present Chiefs of the Bureau of Plant Industry, the Institution is privileged to have the assistance of Messrs. Collins and Kempton for attack upon the fundamentally important question of the origin of maize and to make studies of the maize agronomy of the Maya area. Maize was the cereal which made possible the rise of pre-Columbian American civilization, but its ancestry is problematical and we do not certainly know where, nor even approximately when, it was first brought under cultivation. Thus we can do little more than theorize regarding the place or the time of the beginnings of the higher New World cultures, including, of course, that of the Maya. And the whole career of the Maya, like that of any farming people, must have been most potently influenced by the agronomic possibilities of the lands they cultivated and by the methods which they worked out for growing their staple crop. Without data upon these subjects, gathered by experts, it is impossible to make reliable estimates of size and distribution of population, or to understand the probable way of life of the ancient people.

The Copan Project and the Maize Survey add to a group of researches which was already extensive. The Division is now active archæologically in the Mexican states of Yucatan and Campeche; in Guatemala in the Highlands and Peten; in Honduras. It has also, in cooperation with Field Museum, been conducting excavations in British Honduras. In addition, it is carrying on, independently or with other institutions, studies of the documentary history of the Maya, ethnological and linguistic investigations in Yucatan and Guatemala, work in human geography in the same regions; as well as gathering data, whenever opportunity permits, upon the climate, geology, health conditions and the botany and zoology of the Maya area.

This heavy and varied program has been undertaken with belief that in any historical study one must utilize the resources of many disciplines and take advantage of all possible side-lights. Our investigation, however, is frankly experimental, in that it still remains to be determined whether or not the practical and intellectual difficulties of a coordinated panscientific survey can successfully be overcome. Facts, of course,

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will accrue in abundance. If they be intelligently gathered and clearly set forth, we shall have added significantly to the sum of recorded knowledge. But shall we be able to digest our masses of raw data in such a way as to reach understanding of the all-important whys and wherefores of Maya history and by so doing contribute toward comprehension of the infinitely complex interaction of those biological, environmental and social forces which govern the evolution of man?

Obviously, synthesis and interpretation should be the ultimate goals of all historical research. Particularly must they be held as objectives during prosecution of such a program as ours. For each investigator is brought so quickly into virgin fields, is confronted with so great a body of intensely interesting and puzzling new material that he runs the constant danger of immersing himself in blindly intensive specialization. And in the same way that the individual worker risks entanglement in detail, with indefinite postponement of the essential process of reaching conclusions, so the program as a whole may easily expand and ramify to such an extent that correlation becomes impossible.

There is, then, no clearly discernible stopping place for our work, either in space or in time. Certainly the project should be continued for a number of years. There are certain known gaps in our knowledge which must be filled. Many data have to be accumulated before synthesis can become worth while. A considerable period is required to assemble a group whose members can, by practical experience, be brought to see the benefits of close intellectual cooperation and the pooling of information. So, there being no natural termination for our program, it seems necessary to set an arbitrary time limit by establishing a date when each investigation shall come to a close, all findings be recorded, definite conclusions be stated, and formulation be made of problems for future research. Ten years are believed sufficient to permit current researches to be carried to this stage. New projects will only be undertaken if they can be completed within that time. The arrangement will insure that the older members of the Section's staff shall have completed their work at retirement. And for the younger men it should also be of benefit, for it is good for any student periodically to bring his research to a head, check up, draw conclusions, and make a fresh start.

HISTORY AND THE GEOLOGICAL RECORD

Extension of the term history into periods antedating conscious recording of events by man has carried the study into stages where products of human invention diminish rapidly in number and in complication, until the story of man merges with the record of the rocks as known to the geologist and palæontologist. Recognition of the fact that research on early man involves not only his culture, but the extent of his physical and perhaps his mental evolution through space and time, has made it necessary to bring into careful review also the physical and biological environments through which, and out of which, man has developed. And as the record extends farther and farther into the ancient story of the earth, we find ourselves dealing ultimately with history of an earth without man. But in the steps of advance through those ages before human kind came into being, we recognize development of conditions relating to environment and to change which are also of primary importance throughout the whole period of human existence.

The relation of the Carnegie Institution of Washington to history in the geological sense has until recently touched only here and there an outstanding problem requiring the interest, experience, and capacity of a great investigator. Among the most important of such studies were those of Professor T. C. Chamberlin on the problems of cosmogony, and the investigations of Dr. Bailey Willis relating to critical problems in earth structure. The Institution has also issued a number of important works in the field of geology and palæontology not published readily by other means.

Within the past few decades interest of the Institution has turned toward geological problems as they have grown out of work of the Geophysical Laboratory, and out of seismology. There has also been a definite effort to secure data relating to some of the most critical and most difficult regions of geological history, as represented by the beginnings of geology illustrated in the lowest formations of the Grand Canyon, studied by Dr. Ian Campbell and Dr. John H. Maxson of California Institute. Another important advance has also been made in the story of the beginnings of life as it is known in the second division of the Grand Canyon section, or the Algonkian, investigated by the late Dr. David White. More recently, the work of Dr. N. E. A. Hinds of the University of California has begun to give us a better picture of the whole history of the Algonkian of the Grand Canyon, one of the least known sections of geological time.

In the purely historical sense, work done at the Grand Canyon has large significance, since the Canyon itself is one of the greatest teachers of the meaning and movement of time. As we come to understand more intimately the need for better general appreciation of the concept of time, and its visualization in terms of movement, we shall begin to realize that, with all the importance of the great physical chasm of the Grand Canyon, the story which dominates the picture is that of the lapse of time presented in so spectacular a way.

In that stage where the geological story makes its contact with relatively recent human history, the Institution has coöperated for some years on study of problems concerning early man in various parts of the United States. Especially has this been possible in the south-

west, and more recently through modest aid to Dr. H. de Terra in his examination of problems concerning ancient man of the Himalaya region in southern Asia. The researches in the southwest, carried on by Mr. M. R. Harrington at several points of importance, have been extended in various directions by Dr. E. B. Howard, and more recently through coöperation of Dr. Howard with Dr. Ernst Antevs, Dr. Paul MacClintock, and many others. Out of these studies there is coming a picture of man as present in America at a time when the associated fauna included the elephant and other extinct forms, and when the climatic conditions were somewhat different from those of today. The extension of this work should furnish one of the most interesting chapters in human history.

INTERPRETATION OF CRITICAL PROBLEMS IN SCIENCE

In an effort to make the results of its researches available to science in general, and to the public, a series of carefully prepared lectures on major researches was initiated by the Carnegie Institution in 1921. Through this program the attempt was made to bring together authoritative statements on major researches of the Institution. While the lectures were frequently arranged in groups representing related subjects, in general each statement was independent of the others, and had as its function interpretation of results from a special program of research. The papers presented have in nearly all cases been published, and have been made available to the general reader through magazines, or through the form of releases, or supplementary publications issued by the Institution.

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The lectures in the regular series covering interpretation of research by the Carnegie Institution during the past year have included the following subjects:

"Evolution of Parliamentary Control over the American Colonies," by Leo F. Stock.

"The Surface Features of the Moon," by Fred. E. Wright.

"Nature of the Primary Cosmic Radiation," by Thomas H. Johnson.

"The Igneous Rocks in the Light of High-Temperature Research upon Their Mineral Components," by Norman L. Bowen.

The intensifying discussion of science, and its influence upon conditions obtaining during recent periods of world disturbance, suggested the idea of concentrating attention for a small group of lectures upon subjects relating to the influence of science and research upon current thought. The Trustees of the Institution established such a lecture series in honor of Mr. Elihu Root, whose personal guidance in organization and evolution of the Carnegie Institution has been an influence of very great importance, and whose interpretation of the meaning of science has been of exceptional value in defining the path which research and science should take.

The Elihu Root Lectures of 1934 were delivered by President James R. Angell, of Yale University, and Dr. H. A. Spoehr, Chairman of the Division of Plant Biology of the Carnegie Institution of Washington, on the subjects:

"Popular and Unpopular Science," by James R. Angell.

"The Nature of Progress in Science," by H. A. Spoehr.

In his discussion of the influence of science upon thought, President Angell commented in part upon the subject as follows:

That the applications of science are capable of indefinite further exploitation for the promotion of human welfare, that an unending series of further discoveries will also contribute to this end, and even that here and there the importance of scientific principles as the method of sound progress will be appreciated and adopted—all this needs no proof . . .

. . . There is literally no limit to the ways in which we may thus hope for further help from science itself and from the employment of scientific method. But any deep infiltration into our culture of science in its essential spirit and methods—that will require far longer to achieve.

Despite what has been said above, it would seem to a layman as though economics *must* be a field where dispassionate, scientific analysis and careful conservative deductions and generalizations would be possible and fruitful, and that it both could and should make crucially important contributions to the solution of our problems. Indeed one can only believe that ultimately this will be found to be true. But the present crisis has been marked by incessant and radical differences of opinion among professional economists, who are presumably men of equal intelligence and expert training. Hardly a magazine appears without some article criticizing all preceding economic writers and offering for our troubles a brand new solution put forth as so self-evident as to be axiomatic. And yet we make progress slowly, if at all, in finding the exit from our difficulties. . . .

. . . If science in any important sense is to affect the intellectual quality of civilization, then through education it must be woven into the essential fabric of our culture. To do this will require at best several generations and more than a few profound changes in educational method and objectives.

. . . In any case, what is really important is not so much the prevalence of accurate, up-to-date scientific knowledge, as it is the ingraining deep in the habits of thought of the people, of the practice of careful, critical, unemotional—even skeptical—analysis of every significant issue with a correspondingly conservative process of inference and generalization, so that intelligence may have really free play to make its fullest contribution to the changing social order.

Discussion on the nature of progress in science by Dr. Spoehr was developed naturally from the point of view of

the investigator utilizing as the basis for argument illustration from researches in his own field. Photosynthesis, or the combination of elements in plants under the influence of light, was thus used most effectively.

Among the statements of special interest made by Dr. Spoehr are the following:

Intrinsically there is no reason why there should be any difference in fundamental development in different fields of human endeavor, such as there appear to be in the fields of social activity and those of natural science. They are the products of the same culture, of the same human stock and of the same stage of development. This, however, seems certain, that natural science has been tremendously stimulated by the realization that continuous change must be expected of all things and that such change is not unrelated to past experience. This, it seems to me, has been one of the dominant influences in the development of natural science. As a consequence science has, as it were, taken the offensive in the pursuit of its problems; it has sought out the most difficult of these and has been constantly struggling with them rather than avoiding them or temporizing with them. It has made use of every experience available, accumulated these and in time generalized, preparing for new experiences in the light of the old ones.

The extraordinary advances which have been made in science are to a very considerable extent due to what may be regarded as its remarkable educational system. In the broadest sense education lies in profiting by our own experience and those of others. Research is essentially the gaining of knowledge through experience and the correlating of this into generalized form in which it has wider and more universal value. Without the careful recording of experiences, their correlation, examination in the light of what is already known, sifting of the essential from the irrelevant, etc., knowledge would not grow. This organization of its experiences and constant re-examination of the groundwork on which it is building has been an essential element of scientific endeavor.

PUBLICATIONS

The publications covering results of research by the Institution have been issued by way of all natural channels through which scientific information might be expected to reach the public, or be made of record. Different groups in the Institution have chosen special forms of publication through which their shorter papers have been issued, thus increasing the facility with which the results may be located by other investigators in similar fields.

The publications of the Carnegie Institution of Washington were established to furnish a means for recording and distributing research data not readily brought together in the desired form by other means. The number of publications in this series has maintained a fairly even distribution in relation to the number of members of the staff. At this date the number of volumes issued totals 674.

The Year Book of the Carnegie Institution, established in 1902, has been maintained through the issuing of a volume of general reports upon the activities of the Institution each year. In an interesting form of record these volumes have presented the organization, method of functioning, and contribution of the Institution from all departments. There are few publications that give in so compact a form, and so effectively, the contribution of an institution over several decades of continuous research. It is interesting to observe that the record of this Year Book, by reason of the broad touch with research over the country, gives, in a measure, a picture of the development of science in America since the year of the Institution's founding in 1902.

As is noted in the report of the Editor of Carnegie Institution Publications in 1934, there have been added several

series of publications designed specifically to help in interpretation and dissemination of information regarding technical researches, to which a large percentage of scientific papers are devoted. Of these, the News Service Bulletin serves a wide public in presentation of carefully formulated statements regarding particular researches or fields of research. The Supplementary Publication Series has been based largely upon the publication of papers delivered in the Carnegie Institution lecture series. The Clip Sheet service has helped to bring to the public press portions of statements which may be of so technical a nature that otherwise they would not reach the general reader.

OBITUARY

In the form of organization under which the Carnegie Institution was established in 1902 important place was given to representation of officers under the Government. In accordance with this plan, the President of the United States, the President of the Senate, and the Speaker of the House were ex officio members of the Board. Although this form of representation was abandoned in 1904 for one involving selection of individuals with special reference to personal interest in the objectives and program of the Institution, distinguished members of the Government have continued on the Board. Senator Frederick H. Gillett was a member who prized relationship to this work as an opportunity for aid in a movement which he believed of importance in the scientific, educational, and cultural advance of the country.

First, as Speaker of the House of Representatives, and later as a member of the Senate, Mr. Gillett continued to

give to the Institution the value of his judgment on the relation of science to primary responsibilities of Government. Always interested in the major activities of the Institution, Senator Gillett expressed himself particularly with regard to those which had not only a practical engineering relationship, but presented as well the opportunity for development of major features in our cultural life. Among other activities, Senator Gillett indicated his interest in work of the Institution leading to human interpretation of results obtained in conduct of research on the most fundamental studies of the departments.

BUDGET FOR 1936

During recent depression years preparation of each budget has involved consideration of income conservation, the possibility of which rested upon careful handling of the investment program by the Finance Committee. The Institution has been fortunate in coming through these difficult years without serious impairment of its program, and without the necessity of horizontal reduction of salaries. It is fortunate that the position of the Institution had been bettered in the period immediately before the depression through the contribution of a sum of \$5,000,000 from the Carnegie Corporation, for the purposes of rebuilding and repairing our program, and the carrying out of projects of primary importance which the influence of post-war financial difficulties had made it impossible to realize. Payment of this sum, with accumulated interest, was distributed over a period of five years.

Preparation of a budget for the Institution to cover the year 1936 has required both careful consideration of the financial conditions of past years and the influence which

readjustment may have upon capital and income for the immediate future, as well as for more distant periods. The study of the budget situation has involved also an intensive examination of peculiarities in the nature of the Institution's program, which has been one of the problems under continuous investigation.

Definition of characteristics for an agency like the Carnegie Institution is difficult on the basis of any accepted classification. Although designed particularly for furtherance of research or constructive study, the Institution has been listed commonly as a foundation, by reason of the fact that it is known to have made grants for research. As in relatively few types of agencies, study of the financial structure and maintenance of capital of this Institution has importance with relation to its special program. If the researches were concerned mainly with short-time minor grants, the budget could be expanded or contracted according to income available. If, however, the activities include departments or groups of departments with long-time projects, such as those of the Geophysical Laboratory, the Department of Terrestrial Magnetism, Mount Wilson Observatory, photosynthesis, or historical research, then it becomes necessary to plan a program continuing practically without interruption for periods reaching over many years. Under such conditions it is necessary to set up a budget which can be maintained without greatly diminishing the funds available for the periods over which the approved studies should extend, if full value from them is to be obtained. This situation has definite bearing upon the nature of investments, both as to capital and with reference to the flow of income needed for support of a continuing program.

As has been indicated, there is of necessity a close relation between the expenditure for research at a given moment and the protection of programs which extend a considerable distance into the future. It has therefore been considered wise in preparation of the budget for 1936 to take cognizance of the fact that changes may take place both in value of capital and in the rate of interest upon which income is dependent. It is clearly the part of wisdom so to plan a budget as to build not only in the research sense, on the work already accomplished, but in such manner also as to build back into or upon capital reserves which may serve to maintain capital values and guarantee needed income for the future.

In order to increase the reserves of the Institution, both for capital and for income protection, recommendation was made some years ago that not less than \$50,000 be set aside each year in a special emergency reserve. Such contributions have made possible both the maintenance of income and the accomplishment of certain major elements of constructive work, which could not have been supported from any regular budget. During the past three years additional amounts, up to \$100,000, have been set aside annually to protect income. In spite of great needs at this particular time, when science has opportunity to accomplish much, the budget presented to the Trustees for 1936 is so constructed as to withdraw a still larger sum from income to be added to special emergency reserves and to contingent reserves. These funds can then be drawn upon for the protection of income, if this be necessary, or in the building of capital.

REPORTS ON INVESTIGATIONS

DIVISION OF ANIMAL BIOLOGY¹

GEORGE L. STREETER, CHAIRMAN

Since its incorporation in 1904 there have grown up within the Institution various programs and laboratories for biological research, concerned primarily with the physiology, anatomy, embryology, evolution and heredity of animals. The individual projects were in each case located where it seemed they could be best conducted. In course of time it has been found that in their development these researches tend to overlap and bear one on another, and this has led to increasingly frequent consultation and exchange of facilities between the individuals of the different groups and cooperative endeavors have been found mutually advantageous.

The community of interest that has thus arisen was administratively recognized at the beginning of the present year by the formal establishment of a Division of Animal Biology. Under it are grouped the Nutrition Laboratory located in Boston, the Department of Genetics including the Station for Experimental Evolution and Eugenics Record Office both located at Cold Spring Harbor, the Department of Embryology in Baltimore and the Tortugas Laboratory on Loggerhead Key, Florida.

It will be seen that in the preparation of this report each group has supplied the account of its own activities. A greater accuracy is thereby attained which will offset the disadvantages of any overlappings that may occur or lack of uniformity in the manner of presentation. While the respective accounts should be read in their entirety, a brief summary is herewith given of the different researches of the past year. In some instances there is a blending of different groups but in general the items follow the sequence of the report.

In the field of embryology our most outstanding event during the past year was the obtaining of two primate ova of the ninth day and their subsequent preparation for study. Of almost equal importance were other early macaque embryos which together with those previously obtained now constitute a series that reveals how the egg fastens to the uterine wall, and how from a simple vesicle it becomes converted into an embryo provided with its various envelopes. These early stages of implantation and embryogenesis were heretofore largely unknown for man and the primates, and a wholly new period of development is now revealed for us. Among other embryological studies which have been completed during the year are observations on the earliest appearance of blood-vessels, the development of the amnion, a new analysis of the developing mouse egg, a comparative study of implantation of the ovum, the development of the carotid body, embryological studies of the sloth and the opossum, and the relation of age and dentition in primates.

In cytology, in addition to the structure of the chromosome, observations have been made on the probable functional significance of mitochondria and Nissl substance. Further confirmation has been obtained on the common nature of mononuclear leucocytes, clasmatocytes and epithelioid cells. Tissue cultures of the gonads of the chick and of the hypophysis of the fish have been successfully obtained and studied. Living cells have been exposed to fluorescent dyes and the resultant injuries studied with reference to cell division.

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It has been found that cells irradiated by a carbon arc are thereby rendered vulnerable to fluorescein dyes and that irradiation of the dye is sufficient to produce the effect.

In the field of physiology, studies have been made of resorption of water in the kidney. The factor exerted by gravity on venous pressure has been studied on the tilting table in dogs and cats. The effect upon acuity of hearing of changes in middle-ear pressure has been found to be the result of alteration in the conduction mechanism of the ear. In the physiology of reproduction a study has been made of the cyclic changes which occur in the vaginal epithelium, which study could be conducted under favorable conditions in the monkey colony. Further observations have been made concerning the problem of menstruation and evidence has been found that it may be the posterior lobe of the hypophysis that is primarily responsible. Pregnancy has been prolonged in the rat by induction of fresh corpora lutea, as had previously been done in the rabbit. Certain phases of fetal cardiac and respiratory activities have been studied in goats and rabbits.

In the field of the nervous system a study of interest and of particular importance is one dealing with the plural functions of the pyramidal tract. It is found that this tract contains both excitatory and inhibitory fibers, the latter being separated out to terminate in the hindbrain where they serve to regulate muscle tone and coordination. Further observations have been made on innervation of skeletal muscle, and the sympathetic nerve control of the urinary bladder has been found to be limited to an inhibitory control over the detrusor muscle and is not essential to normal micturition. Audio-electric phenomena have been studied in deaf albino cats. Behavioral studies include a series of observations on the macaque. A new-born baby was separated from his mother and carefully followed throughout the first year of life. A study has also been made of sex behavior of the female macaque correlated with the menstrual cycle and days of ovulation.

Among a group of anatomical studies, mention should be made of the investigations dealing with the comparative morphology of the hand and foot, also of the comparative morphology of the primate kidney and the female genital tract of marsupials. More strictly anthropological studies are those being reported on the stature of Maya men and women; growth of children among Whites, Negroes and Navajos; palmar prints of the Maya; variation in taste-sensitivity in an average population; vital statistics in the town of Pisté, Yucatan. There may also be noted a study on the inherited reduction in teeth.

Investigations in plant genetics have been continued with various species of *Datura*, in which chromosomal differences between species are analyzed through hybridization experiments. Prime types are recognized within individual species and they differ genetically one from another apparently by shifting of ends of chromosomes through segmental interchange, just such differences as are found between species. An important factor in crossability, in which chromosomal hypotheses do not have to be resorted to, has been found to be the ability of pollen of one species to grow in the style of the other, and this in turn depends on the rate of pollen-tube growth and on the length of the style. Mutations have been produced by temperature and moisture conditions injurious to the seed. In this material new characters have

been recognized which can be used in further breeding experiments and will aid in the location of genes in their proper chromosome. Progress has been made in the study of reduction of chromosomes by transferring attention from the pollen mother-cell to the female gametophyte. In the divisions of the latter, lagging chromosomes have been found, and their consequent elimination explains the reduction in number of chromosomes in the egg which is necessary to account for the large proportion of diploids in the offspring of triploid parents.

Increased activity in the study of insect chromosomes has been given a new impetus by the realization of the opportunities offered by the giant chromosomes of the salivary glands. It has now become possible to correlate deficiencies identified by genetic methods, necessarily speculative, with visible structural changes in these large chromosomes. This material should make it possible to carry the analysis of the action of the gene on the organism much further than can be done by genetic studies alone. It has been found in some instances that certain transverse bands are absent in specific deficiencies and in this way it is hoped that a complete chromosome map of the genes can be constructed. On the other hand careful cytological studies of the chromosomes are being made in different insect species which have already yielded important features regarding the basic structure of the chromosome. The first task has been to distinguish to what extent the appearances seen are in the nature of artifacts and to what extent they are actual structures invariably present. By use of photographic technique, evidences on these points have been obtained. Study of deficiencies has been continued by the regular genetic methods, including their experimental production by x-rays. Also observations have been made on inheritance of hermaphroditism in *Drosophila* where it appears that sex determination may be correlated with gene-constitution. This will complement the work being done on sex-control in water-fleas. Newer studies add convincing evidence of the major influence of crowding on the control of sex in this organism.

The studies on leukemia in mice have led to problems of wide significance, such as the nature of malignancy itself. In studies carried on in the Department of Embryology, evidence has led to the belief that malignant cells are permanently and specifically altered ones. This appears to be true also for mouse leukemia. It thus involves an understanding of the relation of genes and cytoplasm in the control of development and heredity. The interaction of the leukemic cells and the hosts in which they are growing is also of importance and has led to the perfection of a method of immunization against leukemia. Immunization can now be established not only by the graded injection of leukemic cells but also can be induced by grafts of normal embryonic tissue, a much safer means. In carrying out these latter experiments, the discovery was made that success or failure depended on the genetic constitution of the tissue used, and this appears to offer a most favorable approach to the testing of the rôle of genes in controlling the differentiation of leukemic cells. In further studies on the nature of the immunizing process, it has developed that mice immunized to inoculations of virulent leukemic cells nevertheless acquire spontaneous leukemia and die from it with the same frequency characteristic of the strain. In other words, different properties are required

to kill leukemic cells that occur spontaneously and the highly malignant cells that are inoculated experimentally.

In the studies on endocrinology, an outstanding result of the year is a demonstration of the dependence of the maternal instinct (rats) upon the hormone, prolactin. Though the mechanism by which the hormone affects nerve or brain function is wholly unexplored, this is an important instance of the participation of a somatic or extra-neural agent in the development of a normal element of the mind. The analysis of the functional control maintained over the organism by the secretions of the anterior lobe of the hypophysis has been advanced. The effect of prolactin and follicle-stimulating hormone is being determined on ovarian tumors of fowls; the former appears to check them and the latter to stimulate them. The method of extraction and purification of prolactin has been improved and assays have been made of the amounts present in various kinds of cattle and at various ages. Important microscopical studies are being made of the hypophysis of the pigeon, correlating the cytology with the different states of activity which occur at different ages. In addition to other observations on basal metabolism in doves and pigeons, a comprehensive study has been completed of the action of the anterior lobe hormones on metabolism of the pigeon at various temperatures. Two notable results should be mentioned. Prolactin as well as thyreotropic hormone was shown to act on heat production, both hormones increasing it in normal and hypophysectomized pigeons measured at or near the critical temperature (30° C.) and both paradoxically decreasing heat production at low temperatures (15° C.). This study also shows that current preparations of the so-called "growth" hormone contain both thyreotropic hormone and prolactin, and probably derive much or all of their heat-producing and growth-promoting properties from these two hormones. This result therefore questions the individuality or separate existence of a "growth" hormone in the anterior pituitary gland.

Other endocrinal studies include those on the female sex hormone which have been made in the Department of Embryology to determine its influence on tumors of the breast and hypertrophy of the breast in male animals. Associated workers have also shown that when a correlation between sex and thyroid weight in newly hatched chicks is made, it is found that the thyroid weighs more in females than in males.

In the field of Eugenics, progress has been made in the determination of the rules by which racing capacity is inherited in the horse. A formula has been perfected by which racing capacity can be predicted among offspring of sires of a given racing capacity. A study has been made of the history of sterilization for eugenical purposes in the different States in this country and an analysis made of the results from various points of view. Mention should also be made of the review of the progress of Eugenics during the past decade, issued as a series of papers gathered in one volume. Among these are studies on leadership as a family-stock quality, race-integrity standards, and a special aptitude test.

In the Nutrition Laboratory physiological researches have been continued in the fields of nutrition, metabolism and bio-energetics. In observations made on large domestic animals, a great variation or lability has been found to

exist in their basal metabolism, and the cause of this variation is by no means limited to the protein content of food. An unexpected amount of heat is produced by the digestive activity following foods consisting largely of "waste" products, such as low protein hay. Aside from food there appear to be other circumstances such as season, lactation, age, sex and probably also the genetic constitution of the animal, all of which have to be considered. These observations will have a practical value in determining the food requirements of different breeds of cattle, according to whether they are to be used for milk production or beef. A comprehensive mass of unique data has been accumulated during past years concerning metabolism and its associated processes as they occur in various forms of animal life, revealing the entire phenomenon in its various aspects. The range of animals studied is being rendered practically complete by the recent addition of one of the largest of mammals, namely the elephant.

Among other studies which are being reported are those on obesity, thyroidectomy, effect of sugars on respiratory exchange, effect on the respiratory quotient of voluntary excessive breathing, and physiological studies of extreme old age. A study is also being reported of the food materials of some of the native American peoples, the Maya of Yucatan and the Navajo and Pueblo Indians.

Mention should also be made of the completion of a new direct-reading respiration apparatus which provides the clinician with a simple instrument by which he may determine the basal metabolism of his patients much more easily than heretofore. Also a technique has been perfected by which the maximum temperature of the expired air, and so the body-temperature, may be determined accurately and rapidly. It provides a feasible way of detecting those individuals, among a given large group, who have abnormal temperatures, as is sometimes called for in schools during epidemics.

During the twelve weeks of its operation, the Marine Laboratory at Tortugas was visited by fifteen investigators. In addition to a continuation of the survey of fishes of that region, their researches included observations on new species of ciliates; regeneration in crustaceans, tunicates and annelids; control of color patterns of coral-reef fishes; cytology of the hypophysis of the shark; correlation between the morphology of the pectoral fin of fishes with its variation in function; effect of variation in light intensity on cytoplasmic structure in the simpler marine organisms; effect of temperature and light on inherent electric potential of *Valonia*; effect of amino acids, tissue extracts and salts of heavy metals on the acceleration of metamorphosis of ascidian larvæ; intracellular determination of hydrogen-ion concentration in ova of marine invertebrates; and photodynamic properties of vital dyes. The last-mentioned study is closely allied to the studies carried on in the embryological laboratory on photofluorescein, noted above.

DEPARTMENT OF EMBRYOLOGY¹

GEORGE L. STREETER, DIRECTOR

EARLY EGG AND IMPLANTATION STAGES

THE UNATTACHED PRIMATE BLASTOCYST

In reporting the obtaining of a 10-day macaque ovum last year, emphasis was laid on its embryological importance and the fact that it extends our vision of the mechanism of development into the 24-hour period, preceding any hitherto known primate embryo. If that was important last year, there is this year to be reported something still more significant, namely the 9-day macaque ovum, another 24 hours earlier. Two excellently preserved specimens representing this stage have been obtained, one a little more advanced than the other. The younger of these is a blastocyst which was still unattached in the uterine cavity and the other was just beginning to fasten itself to the uterine wall. Of all the various stages we could have wished, the latter is the one we would have preferred. It should again be pointed out that obtaining this material is not mere chance but the result of planning, experience and expertness in every step of the procedure. It is the result of good management of the monkey colony and thorough acquaintance with the physiological processes of the animals concerned, and it is equally the result of cunning operative technique followed by the technical requisites for handling, preserving, photographing and sectioning these minute objects. With that much accomplished, any embryologist can now place the material under the microscope and clearly observe in serial sections the structure of the egg at this early period, and he will find, as we have found, many quite unexpected things.

Dr. C. H. Heuser and I have had made a preliminary survey of the 9-day stage and have given an account of it before the American Association of Anatomists. As a free ovum, it consists of a spherical blastocyst having a diameter of 270 micra. The greater part of the blastocyst wall consists of a single layer of thin membrane-like trophoblast cells. At one pole is a germinal mass, the so-called inner cell-mass, a few cells of which, on its inner surface, are already differentiated as an endoderm-like membrane. The remaining cells of the group are still primitive and the overlying trophoblast cells partially blend with them. However, at this time one can recognize the portion of the inner cell-mass that is to form the embryo as distinct from the primitive endoderm below and the trophoblast above. In other words, the ovum by this time is resolved into the primordia of those parts that are to serve as the implanting and nutrition mechanism and are temporary, and the group of cells that are to form the embryo proper and are permanent. A few hours later the blastocyst flattens against the uterine wall, and at the attachment area the trophoblast cells proliferate, the blastocyst wall becomes thicker and at several small areas blends with the maternal epithelium. In this act of fastening, immediate changes occur in the maternal epithelium at each point of contact, consisting of a cytolysis of the cytoplasm and clumping together of the nuclei, which in turn disappear as the surface becomes eroded. As the maternal epithelium disappears, its place is taken by the greatly thickened wall of the blastocyst in a way to preserve the seal of the uterine surface

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intact. All of this happens between the ninth and tenth days following ovulation.

ORIGIN OF THE PRIMATE AMNION

In addition to the much wished for 9-day stage referred to above, Dr. Hartman's colony has yielded representatives of a number of important stages in the period between the tenth and fourteenth days. At present these are being actively studied and preparations are being made to publish a comprehensive account of the embryology of the macaque so that this rare material may be available to all embryologists. The amnion was found to present certain features in its development which were unexpected, and a preliminary account of this has been given by Dr. C. H. Heuser and myself.

It was found that the amnion is in its origin more closely related to the trophoblastic elements of the egg than that part of the inner cell-mass that is to form the embryo proper. Thus in its origin it belongs to the transitional tissues which serve only during uterine life and it is therefore to be grouped with the placenta and yolk-sac. Its function then, as a smooth, fluid-containing serous membrane, providing the growing fetus with ample freedom of movement, would be intelligible in consideration of the nature of its origin.

In the macaque, the central cells of the embryonal ectodermal mass do not undergo degeneration to form a cavity, as we were expecting to find. Instead, the amniotic cavity arises as a cleft between the formative ectoderm and the overlying trophoblast. As the cells of the embryonic ectoderm take form, a concave disk is established, the margins of which are continuous with the adjacent trophoblast cells and the latter rapidly differentiate into a mesothelium or serous membrane, as distinct from the remaining trophoblast. This membrane becomes the amnion and its juncture with the embryo proper remains distinct up to birth.

In the hedgehog it is reported that the amniotic cavity arises as a cleft between the trophoblast cells and the formative ectoderm, just as we now know occurs in the macaque. In the macaque, however, instead of an ectodermal lining spreading up from the embryonal area, as described for the hedgehog, the trophoblast cells constituting the vault of the cleft differentiate into a serous or mesothelium membrane not unlike the pleura or the pericardium.

THE MOUSE EGG

Another contribution to our knowledge of the mammalian egg is that made by Dr. W. H. Lewis and Dr. E. S. Wright. They have studied over 900 living eggs obtained from the mouse. In addition to the morphology of normal and pathological eggs, they have correlated with them physiological observations on the oestrus cycle, mating behavior, ovulation, transport, motility and viability of the sperm. Regarding the age, stage and location of the eggs, they contrived a technique of obtaining the eggs which allowed the determination of what part of the tube they were in. They found that as a rule, up to 24 hours the eggs are in the 1-cell stage and are in the second loop of the tube. Between 24 and 36 hours after copulation, the eggs are in the 2-cell stage and are in the second, third or fourth loop of the tube. Between 44 and 50 hours after copulation the eggs are in 4- to 8-cell stages and are in the fourth to sixth

loops. Between 50 and 70 hours after copulation the eggs are in the 8-cell to morula stages and are in the sixth loop. Eggs older than this, the late morulae and blastocysts, are found in the sixth loop or in the uterine horn.

Important data were obtained by these investigators on the size and volume of eggs. They found that the homogeneous membranous envelope surrounding the egg enlarges rapidly after ovulation, so that there is formed a roomy space between it and the contained egg, the perivitelline space. This increase in size is attained in the first 24 hours, after which the egg-envelope remains constant in size until the expanding blastocyst begins to distend it. The contained egg, or vitellus, undergoes considerable shrinkage, about 25 per cent, during the 1-cell stage and some additional shrinkage during the 2-cell stage. When the blastocyst stage is reached and fluid begins to accumulate in the segmentation cavity, the egg soon regains its original size and continues to grow from then on. It is interesting to note that when the young blastocyst has enlarged sufficiently to just fill the egg envelope, about half of its volume is made up of the fluid which has accumulated in the blastocyst cavity. That is, in the early blastocyst, the cytoplasm is reduced in volume to about half its original size, and now we need to know whether this is simply a loss in water-content.

In studying cleavage it was found that the shape of the cells up to the blastocyst stage is dependent on their surface tension and their resultant adhesion to one another. As the fluid of the segmentation cavity begins to accumulate between the trophoblast and the inner cell-mass, another factor enters, namely, the pressure of this fluid upon the surrounding cells. The flatness and thinness of the trophoblast wall from then on increases as the blastocyst fluid increases. Other contributions made by these investigators include observations on the change in the character of the cytoplasm as it is followed from the ovary to the tube and the effect of fertilization and the subsequent events of cleavage. They also made numerous observations on the abnormal egg and have supplemented them with a series of excellent photographs for the benefit of those who can not see the original material.

TYPE OF MAMMALIAN IMPLANTATION

During the past winter, Dr. H. W. Mossman of the University of Wisconsin was guest in our laboratory for the purpose of studying the phenomenon of implantation and placental formation from a comparative anatomical standpoint. Before coming, he had already accumulated much data, which was particularly complete for the rodents. With us he applied himself to the determination of the homologies existing between placentation of other mammalian forms and the phenomenon as seen in monkeys and man. Some preliminary statements of his observations have been reported; a complete account with full illustration is now in the course of preparation and is scheduled to appear in a coming volume of the Contributions to Embryology.

ORGANOGENESIS

EARLY ANGIOGENESIS IN PRIMATE EMBRYOS

The study of Dr. A. T. Hertig on the formation of the primitive mesenchyme and the differentiation of the first capillaries in the chorionic wall

has been completed during the past year and is now in published form. Utilizing a considerable series of very early human ova and being able to compare this material with macaque embryos of corresponding age which were in ideal histological condition, Dr. Hertig has been able to give an adequate account of this important period of the vascular system and has carried the principle of early specificity of tissues another step forward.

In this study it is found that both the primary mesoderm and the first angioblasts arise from the trophoblastic, or chorionic, envelope of the ovum. While still in the blastocyst stage, before any villi have formed, vascular primordia and primary mesoderm cells can be seen delaminating from the inner layer of trophoblastic cells and at the same time differentiating from the trophoblast and from each other. Once established, the vascular primordia possess the power of independent growth, migration and lumen formation. Branching elements from primary foci may become discontinuous and so constitute new foci which later may become reconnected or connected with other foci. Thus angiogenic foci appear first in the region of the primary placenta and later in the future body-stalk and around the yolk-sac.

As the chorionic villi form, there is simultaneous differentiation of new vascular foci and mesenchymal stroma. The column of proliferating trophoblastic cells which compose the new villus becomes hollowed out by the resolution or differentiation of the central cells into angioblasts and mesenchymal strands. All primitive villi during the formative stages appear to derive their vascular primordia in this manner. As the villi grow, vascular networks are formed by coalescence of secondary sprouts growing from isolated angioblastic primordia and thus the secondary villi and lateral branches are found connected with the primary villus. Later as the villi become complex, the vascular primordia show a tendency to become discontinuous, a process of vascular adjustment which continues late in embryonic life.

So long as primitive villi continue being formed, Dr. Hertig finds evidence of new angioblastic foci and primary mesenchyme, and we thus may assume that the trophoblast from which these new villi are derived retains its primitive character and potentialities. In other words the trophoblast constitutes a primitive tissue in which the segregation of its derivatives is not yet complete. In connection with this study, mention should be made of the successful use Dr. Hertig made of the glass-plate method of reconstruction. With it he obtained records which for the first time adequately represent the capillary development in early chorionic villi of human embryos.

ABNORMAL DEVELOPMENT

A rare anomaly of the eye, known as anterior lenticonus, has been studied by Dr. B. Rones. In this condition there is a conical projection of the anterior surface of the lens into the anterior chamber of the eye, resulting in a marked disturbance of vision. Dr. Rones has concluded that it results from faulty development, involving the differentiation of the lens fibers in the central region of the lens. He was able to recognize the anomaly in an early stage, in an 18-mm. human embryo. In his specimen, the lens fibers

of the central part have failed to obliterate the lens cavity which normally occurs before then. Thus there persists in this lens a lakelet of homogeneous serous fluid under the anterior epithelium, and it is evident if this embryo had gone on it would have been born with this congenital lens defect. On account of the rarity of the defect, little is known as to its genetic character.

We are indebted to Dr. J. L. McKelvey and Dr. J. S. Baxter for the application of a study of malformations of the vagina and genito-urinary tract to the problem of the normal development of these structures. Their observations were made on a monstrous female term fetus. In this case there had been an arrest in the development of the urogenital sinus and one of the consequences was a considerable defect in the lower part of the vagina. The upper part of the vagina could be recognized and into it there opened the two cervixes of two uteri. The Müllerian ducts had differentiated, but there was a nonunion of the urogenital folds.

CAROTID BODY IN HUMAN EMBRYOS

The carotid body is a small blood-pressure mechanism which forms bilaterally in the mesoderm in relation to the third branchial arch artery and the glosso-pharyngeal nerve. Its development in the human embryo has been studied by Dr. J. D. Boyd who, as Fellow of the Rockefeller Foundation, has been guest of this laboratory during the past year. Dr. Boyd finds that the primordium of the carotid body can be definitely recognized in human embryos 13 mm. long. At that time it consists of a condensation of cells surrounding the third-arch artery above the origin of the external carotid artery. This collection of cells is closely related to a branch of the glosso-pharyngeal nerve and has no apparent connection at that time with the sympathetic nervous system. In embryos of 15 to 20 mm. C. R. length, the lumen of that region of the carotid artery becomes altered and an extension of it penetrates into the condensation, which now is more marked on its medial and anterior sides. In 22- to 30-mm. stages the condensation loses its intimate connection with the artery as the latter acquires its medial and adventitial coats. At the same time the condensation becomes larger, from an influx of cells from the glosso-pharyngeal, vagal and perhaps from the sympathetic ganglia. The point to be particularly noticed is that if cells of sympathetic origin reach the carotid body they do so after the 18-mm. stage and therefore it can not be regarded as primarily related to the sympathetic system.

BRADYPUS AND MARSUPALIA

In numerous respects the sloths (*Bradypus griseus*) show in their embryological stages a striking degree of similarity to human embryos. Obviously there can be no close generic affinities between these widely separated forms, and the similarity is only to be explained as an example of convergent evolution, a phenomenon which seems to be constantly forcing itself upon our attention. Four young specimens obtained at Barro Colorado Island by Dr. Enders have been studied by Dr. C. H. Heuser and Dr. G. B. Wislocki. Three of these possess 3-, 7- and 12-paired somites, respectively, and the anterior limb buds are just appearing (38 somites) in the fourth.

The analogies found between sloth and man concern particularly the relationships and structure of the body-stalk, amnion and yolk-sac, all of which are extra-embryonic parts. The endodermal allantois is rudimentary as in man. The blood-vessels of the body-stalk have more to do with the vascularization of the chorion than with that of the allantois. The amnion is reflected on the body-stalk with a prolongation toward the chorion in much the same way as in man. Finally the yolk-sac is temporarily attached by a pedicle to the opposite wall of the chorion, much in the same way as has been noted in certain human specimens. The rudimentary allantois of the sloth seems also to be present in the armadillo, but otherwise the body-stalk and yolk-sac of the armadillo abruptly diverge with their own specializations. One can, to his taste, find similarities or differences, for both are present in abundance, as if to confuse us. The phylogenist must therefore proceed with caution.

A detailed study of the development of the genital tract of the opossum has been completed by Dr. J. S. Baxter, and because of the special features characterizing the marsupial arrangement of this tract, and particularly of the vaginal apparatus, his observations will be of wide interest. Dr. Baxter's investigation was mentioned in my report of last year. Since then he has become a Staff Member of the Anatomical Department of McGill University. His work in the meantime has reached publication in its final form. The material used in his study covers the period of the last three days of uterine life and the first seven weeks of pouch existence. Thus he was able to follow the early development of the Müllerian duct, the formation of the primordia of the lateral vaginal canals and the subsequent transformation of the latter into the adult form of vaginal apparatus. He finds that the opossum conforms to other mammals in that the Müllerian duct is not derived from the Wolffian duct, but arising by an invagination of its own special area of coelomic epithelium its tip proliferates and extends caudally along the Wolffian duct, as along a guide rail. The caudal growth of the Müllerian duct brings its tip into contact with a diverticulum of the urogenital sinus with which it fuses. This diverticulum, called the sinus horn, becomes converted in a solid epithelial cord of cells which surrounds and replaces the lower end of the Müllerian duct. The Wolffian duct is also connected with the sinus horn, but plays no part in the formation of the derived epithelial cord. Dr. Baxter shows that it is the prolongation and differentiation of the latter that are to form the caudal one-third of the lateral vaginal canal, the cranial two-thirds being derived directly from the Müllerian duct. This apparently is not true for all marsupials, for in some of them the Wolffian duct forms the lower segment of the vaginal canal. Nature appears to abhor rules.

CYTOLOGY

CHROMOSOME STRUCTURE

An important advance in the analysis of chromosome structure was made by Dr. C. W. Metz and his coworkers when they found that they could arbitrarily vary the structural appearance of the chromosome by the manner of handling the tissue and by the type of fixative used. In these studies they

used the large chromosomes found in the salivary gland of the fungus gnat (*Sciara*) and which were especially favorable for their experiments. If the tissues were dissected in dilute salt solution or in tap water and then fixed and stained in the customary iron-aceto-carminc mixture, the chromosomes are found to contain segmentally arranged chromatin bands or disks of various thinness down to thin lines or a thin layer of granules and many of these bands are in pairs. On the other hand if the tissue is dissected in body-fluid or directly in the aceto-carminc mixture, the chromosomes are found to contain, instead of bands, flattened vesicles, the larger ones being like compressed biscuits and the thinner ones ranging down to mere lines or rows of granules. In each case there is constancy in this organization, that is, homologous regions of homologous chromosomes correspond as to thickness or thinness, whether they are bands or vesicles.

The vesicles may be large enough so that one can make out a vacuolated or alveolar structure, and where the trabeculae join the stainable material is increased, giving the appearance of granules. This vacuolated structure extends into the intersegmental region and by proper stretching one can produce the appearance of longitudinal lines on which the granules appear to be threaded. Apparently the latter is an artifact of little significance. The important fact, however, is that each region or level of the chromosome has a definite type of transverse structure which changes abruptly from one region to another. At some places the protoplasm appears to be homogeneous, while at others it is either coarsely or finely alveolar. These morphological differences evidently are the expression of qualitative chemical differences.

As a further means of eliminating artifacts Dr. Metz together with Dr. W. L. Doyle studied the living nuclei in the intact uninjured gland. It was found that the glands could be mounted in body fluid surrounded by mineral oil and the nuclei examined under the microscope under essentially normal conditions. They also were able to vary the salt content of the fluid and introduce various chemical reagents and observe the induced changes. It was found that in the normal living state the chromosomes constitute about 90 per cent of the volume of the nucleus and are invisible and do not show transverse bands or vesicles. Other than the chromosomes, the nuclei contain a granular material and in the spaces between it are the coils of the homogeneous chromosomes. When the nuclei are injured and begin to degenerate, the chromosomes shrink and transverse bands become visible and these changes can be followed under the microscope. Acetic acid causes a violent shrinkage in chromosome volume, estimated from 50 to 75 per cent. Hypertonic salt solutions cause moderate shrinkage and this change may be reversed by addition of hypotonic solutions. As the chromosomes shrink and the transverse bands become visible, one can see that they occupy regions which were previously optically empty. With increasing shrinkage the transverse bands become thicker, more irregular and granular. The marked shrinkage following acetic fixation occurs principally in the intersegmental material, and it is for this reason that the transverse disks give the chromosome a ribbed appearance, since the granules are so greatly modified by the character of fixation it becomes unlikely that they can represent genes.

RELATION OF CHROMOSOME STRUCTURE TO GENES

The favorable nature of the salivary gland chromosomes of *Sciara* has led Dr. C. W. Metz and Miss E. H. Gay to analyze chromosome organization in relation to genes.

They find, both in fixed and living material, evidence that all chromosomes in *Sciara* are composed of two chromosomes united side by side, retaining more or less completely their identity. They appear to have united at a late stage, after they have attained their large size and after their banded structure is developed. They thus are ribbon-like with a longitudinal groove marking the junction of the two components and tend to be spirally twisted about each other. Other than this there is no evidence found of longitudinal organization into cables of gene strings. The transverse segmentation into vesicles or bands is, on the other hand, very striking and these segments show characteristic differences in size and structure, producing a pattern which is constant in homologous chromosomes of different cells and individuals.

The problem now facing the cytologist is whether these vesicles and bands represent genes or whether the genes are represented by the granules which mark their surfaces, following suitable treatment. It is of course possible that the genes may be located in the intervening clear areas between the vesicles or in the clear substance within the vesicles themselves. Some light is thrown on this by the fact that in one species (*Sciara ocellaris*) one chromosome of a pair contains a transverse segment or vesicle not present in its mate, though otherwise they match level for level. In other words, one of the two chromosomes of the pair possesses this particular segment and the other lacks it. This extra segment is found regularly in each nucleus of these individuals and is constant in form and serial position. It is normally present in about half of the females and probably also in the males. If this proves to be a single gene locus, as seems possible, we may then roughly calculate the total number of similar gene loci in the haploid set of chromosomes as between 1500 and 2000, which should be sufficient if a liberal view is taken of the limitations of the gene.

An important review of the structure of the salivary gland chromosomes has been published by Dr. Metz, with a striking series of enlarged photographs which will serve to make a wide range of readers acquainted with this new field of exploration—a field which appears to have great promise.

MITOCHONDRIA AND NISSL SUBSTANCE

Evidence as to the rôle of mitochondria is still meager and any observations bearing on it are welcomed. Thus the studies of Dr. W. L. Doyle on one of the protozoans are of interest in that the distribution of the mitochondria in these primitive organisms indicates that they are placed where there is ample opportunity for an interchange of materials with the surrounding medium. In the pseudopodia of the foraminiferan studied by him, it is only the mitochondria that flow out into their hyaline cytoplasm. There appears to be a segregative mechanism by which the mitochondria are carried by the streaming currents from the central protoplasmic mass of the organism, whereas other equally small bodies are not. They may be larger than the cross-sec-

tion of an individual pseudopod and yet flow out into these myriads of anastomosing pseudopodal processes where they meet and pass other mitochondria which are returning to again mingle with the various constituents of the central mass. Whatever the rôle of the pseudopodia, it is probable that mitochondria are closely related, whether it be the elimination of waste products, absorption of food or possibly as a contractile mechanism. The organism (*Iridia diaphana*) used in Dr. Doyle's study is well adapted to cytological research because of its habit of leaving its shell and crawling about naked, with its inner structure observable to the microscope. Of the various substances composing its cytoplasm, the mitochondria could only be confused with calcium oxalate crystals, but from these the former can be distinguished by means of polarized light.

In my report of last year mention was made of the observations of Dr. L. Einarson on the chromatin in nerve cells and its different physiological states, demonstrating that a considerable change in stainability is normal for nerve cells. This work has been extended to cover the problem of the "Nissl" bodies which have played a large rôle in experimental neurology and neuropathology. Dr. Einarson, after an analysis with a great variety of fixatives and stains, concludes that the Nissl pictures represent more or less constant precipitation patterns regardless of the variety and the hydrogen-ion concentration of the fixative used. He further concludes that there are at least two colloidal substances present in the protoplasm of the living nerve cell. One of these is a fluid one which represents the dispersed phase and, after coagulation, constitutes the so-called Nissl bodies. The other is a highly viscid semi-solid or plastic substance of considerable density which represents the continuous phase and determines the typical formation of the Nissl bodies by a pattern which may be left unstained. Because of the constancy of this pattern it must be assumed that the determining factors are present in the living cells. Neurofibrils are a constituent of the continuous colloidal phase and thus may be assumed to play a rôle in the formation of the Nissl bodies. Dr. Einarson did not attempt a chemical analysis of the Nissl substance, but he was able to demonstrate histologically three separable components, (1) a basophil chromatin substance, insoluble in warm water but soluble in acids and a solution of Na_2CO_3 ; (2) basophil protein, soluble both in warm water and acids and a solution of Na_2CO_3 ; and (3) an acidophil protein, which is insoluble both in warm water and acids and a solution of Na_2CO_3 .

TISSUE CELLS STUDIED IN CULTURES

WHITE BLOOD-CELLS

In previous reports I have outlined the evidence that led to the view that mononuclear blood-cells, clasmatoocytes, epithelioid cells and giant cells, though differing so widely in appearance, are but functional states of the same cell. Dr. D. L. Reeves has returned to this problem and by combining several types of experimental procedures has further substantiated this view. He has done this by running parallel tests of mononuclear cells of the blood and of connective tissue under similar conditions in the animal and in tissue culture.

As a suitable foreign substance, red blood-cells of the rabbit were injected into the subcutaneous tissue of the rat and at varying periods the tissue monocytes were obtained and examined to observe the progress of phagocytosis. Cultures made from such tissue were found most favorable for observation. In this way it was demonstrated that monocytes become fewer and macrophages become more numerous after the first five hours and after 48 hours epithelioid cells begin to appear. Similar results were obtained following the injection of human tubercle bacilli and also bovine tubercle bacilli. In the latter case the transition is slower, but after five days explants of tissue showed no monocytes, whereas there were many large macrophages and an increasing number of epithelioid cells.

Cultures were also made of white blood-cells of the rat separated from the red cells by means of the centrifuge. Here too, following incubation, there occurs a decrease in the monocytes and a corresponding increase in the number and size of the macrophages and finally the presence of epithelioid cells. When foreign material is admixed (rabbit red cells or tubercle bacilli) the transition of monocytes into macrophages is more rapid.

As a final substantiation, individual monocytes were kept under observation for varying periods of time and their increase in size and character followed as they became transformed into typical macrophages. On the other hand there was no evidence that the reverse process occurs—that macrophages change into monocytes. Nor were lymphocytes ever seen to behave like monocytes in the matter of becoming transformed. They and the polymorphonuclear leucocytes always died after a few days.

Dealing with another activity of the white blood-cell, Dr. W. H. Lewis has investigated the manner and rate of locomotion of the polymorphonuclear neutrophile which is the common white cell. He utilized for this purpose the motion picture film as the record of form and position from moment to moment, in essentially the same way as previously done for the lymphocyte. As in the case of the lymphocyte, he finds that the neutrophile in its migratory movements maintains an anterior pseudopodal end and a posterior tail end. Also a series of constriction rings form from time to time at the base of the pseudopod through which the softened center of the cell is pressed forward by the contracting shell. An outer plasmagel layer forms in front of each constriction ring, and at the same time the inner surface undergoes continuous solation to be forced forward into the advancing pseudopod by the contracting periphery of the body of the cell. In 20 neutrophiles studied, the rate of locomotion averaged about 20 microns per minute, which is a trifle slower than the lymphocyte rate under similar conditions.

GONADS OF THE CHICK

Cultures of the ovary and testis of the chick have been successfully made by Dr. G. Muratori, who as a Rockefeller Fellow has been a guest in this laboratory during the past year. The embryonal ovary of 5- to 21-days incubation when cultivated shows a migration of germ cells, stroma cells and lipoid cells. The germ cells migrate either singly or in clusters of 2 to 20 cells and also in multinucleated masses having 2 to 25 nuclei. They exhibit a characteristic arrangement of chromatin in the nucleus at different stages

and possess a typical mitochondrial crescent. Cultures of the testis exhibit growth of the stroma and of isolated germinal elements. This study has been reported by Dr. Muratori as a preliminary communication and at present it is being prepared in final form for the Contributions to Embryology.

CULTURES OF THE HYPOPHYSIS IN FISH

In some fish, particularly the dogfish and skate, the lobes of the hypophysis can be easily separated. Advantage has been taken of this by Mrs. M. R. Lewis and Mr. P. S. MacNeal for studying the component cells of the respective lobes. Cultures, at room temperature, were made of all three lobes, after a suitable medium had been found. The *pars nervosa* gave extensive outgrowths of delicate fibrils within 12 to 24 hours and attained their maximum by the 48th hour.

Growths from the glandular portions took the form of epithelial membranes, which began by the second day and continued for two or three weeks, forming wide-spreading sheets. The epithelial cells were often ciliated and the cilia continued to beat for 8 to 10 days. Patches of granular cells were present throughout the membrane, growing out especially from the intermediate lobe. From the ventral lobe, which is peculiar to the selachians, many large cells full of large colloidal granules migrated out, giving them a frothy appearance. These did not appear to multiply. This study is being continued by Mrs. Lewis and Mr. MacNeal and it promises to throw much light on the comparative histology of this obscure organ.

MALIGNANT CELLS

In the form of a presidential address, Dr. W. H. Lewis has reviewed the problem of the malignant cell and has brought together and analyzed his own observations on tumor cells, and those of his coworkers, extending back a number of years. Reference has already been made to these studies, from time to time, in previous Year Books. According to the view now held by him, malignant cells are permanently altered ones. They are new types or species of cells that arise in the body from normal cells which have been altered by environmental influences or agents of one sort or another. Apparently it is a cytoplasmic alteration rather than a chromosomal one. The alterations appear to be irreversible under the ordinary conditions in which the cells live and multiply. It is conceivable, however, that malignant cells of one type might be changed into other types or reconverted into normal cells by providing the requisite environment.

After malignant cells are once established, they multiply independently of the special environment or agents which produced them and the growths can be continued indefinitely through transplantations from animal to animal and through tissue cultures on glass slides.

Though the exact process by which the normal cell is transformed into a malignant cell is not understood, the differences between the two after the alteration has occurred are fairly definite. This includes the uncontrolled multiplication of the malignant cell and its disorderly growth. There are also cytological differences between the normal and malignant, as well as between different malignant types. These differences are slight, but they

are multiple and involve the whole cell, and in their combination they enable the experienced student to recognize with considerable accuracy the type with which he is dealing.

Chromosome irregularities are very common in malignant cells, but because of their variation as compared to the constancy of the cytoplasmic characters, Dr. Lewis regards them as secondary to the alterations in the other parts of the cell such as the cytoplasm or centrosomal system. In other words the cytological characteristics of malignant cells, at least after they have become differentiated, are not dependent on the maintenance of an exact chromosome formula and so are not to be explained by genes, and hence are something other than mutants, in the sense given that word by the geneticists. This review by Dr. Lewis tends to clear the ground and will help in planning further exploration in this important field.

In a study of mammary gland tumors in mice, Mrs. M. R. Lewis and Dr. L. C. Strong found that cultures of these tumors are affected differently by certain chemical agents (ascorbic acid, dibenzanthracene and fluorescent X) than cultures of normal chick embryo tissue. The first two inhibited the growth of the cultures, and fluorescent X, instead of remaining in bright red granular form as it does in normal cells, tended to be grouped in clusters of yellow crystals within the vacuoles of the cancerous cells. So here again the cancer cell is behaving differently from the similar normal cell.

The study of Dr. W. Schopper of the Walker rat carcinoma No. 72 has been published in its final form in the Contributions to Embryology. This study has been mentioned in a previous report. It concerns a simple carcinoma which has been cultivated several years by subcutaneous inoculation from animal to animal. It is characterized by the great activity of the growth of its stroma cells. The latter are found to arise primarily from the endothelial cells of the capillaries of the explant.

ADVANCE IN TECHNICAL PROCEDURES

The opportunities afforded by the Mount Desert Island Biological Laboratory have been utilized by Dr. H. Hibbard to explore various tissues of cold-blooded animals suitable for growth in culture at room temperature. Growths were obtained of lobster heart cells, epithelium from snake kidney, epithelium from skate and dogfish kidney, gonads of frog, and various Lepidopteran tissues. The gonads of large tadpoles grown in frog plasma or diluted chicken plasma gave uniformly good results. After 7 to 10 days large numbers of dividing cells could always be found. Such growths remained in good condition for three or more weeks without change of medium.

The improvement of the roller-tube culture method by Dr. W. H. Lewis, originally developed by Dr. Gey, has made it possible to cultivate malignant cells of different rat tumors over prolonged periods. In this manner pure colonies of tumor cells have been obtained which maintain indefinitely their peculiar characteristics, their malignancy and their power of growth. The colonies and the cells of these tumors differ one from another and from normal cells. The difference of the colonies can be recognized with the naked eye. Further experiments are necessary to determine the optimum medium for each sort of malignant cell. Tumor tissues, however, have been cultivated in suffi-

cient quantity for making metabolic tests. The roller-tube method appears to have advantage over the Carrel flask method in ease of manipulation, prolongation of transfer periods and changes of supernatant fluid. Whether it will be possible to carry on, year after year, various tumors by this method more satisfactorily than by transferring them from animal to animal is not yet determined. A full description of the method and the media employed has recently been published in the Contributions to Embryology (vol. 25).

PHYSIOLOGICAL STUDIES

FLUORESCENT DYES AND LIVING CELLS

Fluorescent X, a dye derived by reducing neutral red, has been applied to cultures of chick embryo tissue by Mrs. M. R. Lewis. She finds that it is taken up rapidly by the cells and is accumulated in the granules as a bright yellow color, the other elements of the cells remaining unstained. At the end of the first or second day the stained granules become oxidized to neutral red and remain red until the cell degenerates, when the dye regains its reduced, yellow form. The clasmatocytes are particularly active in accumulating the dye and their location makes no difference, the deep-lying ones staining as brilliantly as those near the surface.

It is of particular interest that along with these color reactions, certain abnormalities occur in the cells undergoing mitosis. These abnormalities are limited to the period while the dye is in the reduced yellow state. In the presence of the dye, the ends of some of the chromosomes adhere, resulting in delayed separation. This lagging of some of the chromosomes results in an unequal distribution of the chromosomes in the daughter nuclei. When strong concentrations of the dye are used, many chromosomes remain attached at their ends and separation is accomplished only by the constriction of the cytoplasm and the daughter groups of chromosomes are squeezed apart after the manner of amitosis. These observations have a bearing on the elimination of chromosomes described in *Sciara* by Dr. Metz and his coworkers. The dye fluorescent X is a product of the laboratory of Dr. W. Mansfield Clark, who kindly placed some of it in crystalline form at the disposal of Mrs. Lewis for these experiments.

In referring to environmental influences on the growth of normal and malignant cells, reference was made in my report of last year to the observations of Mr. J. F. Menke, who found that in the presence of certain fluorescent dyes the cells of cultures will die provided they are irradiated by a carbon arc. Neither the dye alone nor the irradiation by itself is effective. During the past year, Mr. Menke has completed his studies on these photodynamic actions for publication in the Contributions to Embryology. His observations make it clear that the dye does not become effective on the living cell until irradiation has produced its effect and the entrance of the dye into the cell with its injurious consequences only follows after changes are produced in the cell membrane. The investigator studied a variety of normal tissues and also malignant cells. In general the results were similar. There was found, however, a greater increase in optical density of the malignant cells after irradiation, whereas cytolysis and bleb-formation were more marked in

the normal cells. In both normal and malignant tissues, certain types of cells (e.g. connective tissue) were more resistant to irradiation than others.

Recently Mr. Menke has been endeavoring to determine if the photodynamic action referred to in the previous paragraph is not to be explained by the effect of the irradiation upon the dye. With this in mind he prepared a *photofluorescein* by subjecting a solution of sodium fluorescein to concentrated rays of sunlight over a prolonged period. When red blood-cells are subjected to this material, they undergo hemolysis in the dark to the same extent that they do when treated with fluorescein in the light. On the other hand, unirradiated fluorescein has no apparent hemolytic action in the dark. He has also found that even a short irradiation of the dye produces enough of the photocompound to cause a partial hemolysis. Also if the dye is in contact with the cells during irradiation, it requires but a short period to produce pronounced hemolysis. It is clear that some changes are produced in the molecule by the irradiation, indications of which include the complete disappearance of the fluorescence of the solution of sodium fluorescein after prolonged irradiation and the shifting of the absorption spectrum of photo-fluorescein toward the red end of the spectrum.

RESORPTION OF WATER IN THE KIDNEY

As a means of demonstrating more definitely the mechanism of antidiuresis, Dr. I. Gersh has conducted a series of experiments in the rat, utilizing the principle of intravenous injection of ferrocyanide and determining its elimination through the kidney by histochemical tests (presence of Prussian blue) of the sections. By observing the relative density of ferrocyanide in the lumen of various portions of the urinary tubules, a record was obtained of the sites of water absorption.

When a normal rat is tested, one finds the Prussian blue principally in the loop of Henle and the distal convolution and none of it in the glomeruli, blood-vessels or in the kidney epithelium. In rats made diuretic by intraperitoneal injection of tap water, the kidneys are well-washed out and only a small amount of Prussian blue is found in the loop of Henle. On the other hand, when rats are made antidiuretic by injection of pituitrin, a substance from the posterior lobe of the hypophysis, sections of the kidney still show no Prussian blue in the glomeruli but it is very dense in the thin portion of the loop of Henle and more than normal in the proximal convolution of the urinary tubule and slightly increased in the distal convolution. It is at these points therefore that the water is reabsorbed in pituitrin antidiuresis as is proven by the Prussian blue left behind as a deposit.

With these observations in mind, Mr. A. Brazier Howell and Dr. I. Gersh have given their attention to *Dipodomys*, a small desert rodent which is able to live for prolonged periods without a visible water supply. These animals were kept in the laboratory on a diet of dry rolled oats, without water, for periods up to three months, without loss of weight or other evidence of deterioration. In nature they appear to survive indefinitely with no moisture except that obtained from their food and from metabolic water of their own systems. Of the latter, there appears to be no more in *Dipodomys* than present in other mammals.

These investigators after demonstrating that the chief sites of urine resorption in *Dipodomys* are similar to those found in the white rat, compared dry-fed and wet-fed *Dipodomys* with similarly treated white rats. They found that the dry-fed white rat reabsorbs its urine in the kidney by utilizing its normal mechanism to an augmented extent, whereas the dry-fed *Dipodomys*, in addition to utilizing its normal mechanism, supplements this by a greater resorptive activity of the larger ducts of the renal papillæ. In addition to this the dry-fed *Dipodomys* was found to be able to resorb water through the walls of the urinary bladder. This interesting little animal therefore proves to be a superb conservationist.

MEASURING THE GRAVITY FACTOR IN VENOUS PRESSURE

As a means of checking the part played by gravity in determining venous pressure, Dr. J. H. Clark, Dr. D. R. Hooker and Dr. L. H. Weed have conducted a series of experiments in which the venous pressure was first recorded in various body parts and then the change in these readings was recorded when the animal (dog) was tilted from horizontal to head-up and head-down positions. Because of the varying relative elasticity of the different parts of the vascular system it was found that the reference point from which the hydrostatic factor is to be measured can only be located by direct determinations as was done in their experiments. They found that the heart is not the point from which the hydrostatic factor is to be measured. In the dead animal where the venous system constitutes an unbroken column from head to tail, the hydrostatic pressure in the vertical position is measured from a point 8.2 cm. caudal to the heart, in an animal about 50 cm. spinal length. In the living animal the situation is different, since in that case the venous system is interrupted by the heart and there are thus two columns. In the tail section the reference point for measuring the gravity factor lies 12.1 cm. away from the heart and in the upper section it lies 3.8 cm. from the heart. Similar experiments were carried out on cats and the reference points were found to be similarly situated. Up to this time it had been generally accepted that the influence of gravity was determined by the level of the right auricle and amounted to the height of the column of blood between that level and the point measured.

MIDDLE EAR PRESSURE AND AUDITORY ACTIVITY

A series of experiments has been carried out to determine the effect of changes in middle-ear pressure on the transmission of sound stimuli, the effect on function being recorded by the Wever and Bray phenomenon. In these experiments Dr. H. A. Howe has cooperated with two investigators of the Otological Research Laboratory. This is the first time that direct measurements of middle-ear pressures have been made with the necessary experimental facilities for measuring the functional ability of the ear and their results are therefore of particular interest. They have found that either increased or decreased ear pressures impair the functional ability of the ear and in about the same degree. The impairment is directly proportional to the amount of pressure exerted. A minimum pressure, however, is required to produce impairment and this was found to be plus or minus 5 mm. of mer-

cury, corresponding to 300-foot variation in altitude. In the impairment, low and high frequencies are affected more than those in the middle range. These investigators conclude that the pressure change does its damage through the conduction mechanism of the ear, and thus they have a new tool for determining the nature of auditory conduction.

REPRODUCTION AND ENDOCRINE STUDIES

CYCLIC CHANGES IN THE VAGINAL EPITHELIUM

A striking hormonal phenomenon associated with the ovarian cycle has been studied by Dr. M. E. Davis and Dr. C. G. Hartman. Taking advantage of the fact that the menstrual cycle of the macaque largely parallels in character and time interval the same phenomenon in the human female and also the advantage that ovulation can be recognized with greater precision in the former, they have investigated the changes that occur in the vaginal epithelium of the macaque in correlation to menstruation and the ovarian cycle. With a specially constructed instrument they were able to obtain small samples of the vaginal mucosa in a series of animals at weekly intervals and always taken from the same region. These pieces were carefully fixed, sectioned and stained for microscopical examination.

That the vaginal epithelium undergoes a definite cycle of building up and breaking down somewhat like that of the uterine mucosa was clearly demonstrated. It was found that the epithelium regularly reaches its greatest thickness at the time of ovulation. It then consists of an active basal layer and a thick inactive functional or surface layer. The two are separated by a narrow, deeply staining zone of cornification. Following ovulation, the functional layer begins to desquamate and may completely slough off, greatly reducing the thickness of the epithelium. Beginning with menstruation, mitosis becomes active in the basal layer and the epithelium regains once more its maximum thickness near the time of ovulation. The purpose served by this tidal change in the epithelium is not understood. These investigators, however, were able to demonstrate that it is linked with ovarian physiology. Cessation of ovarian activity (menopause) or abnormally prolonged ovarian activity (persistent atretic follicle) result in corresponding alteration in the vaginal picture. During pregnancy, in the early weeks, the epithelium remains in the high, completely layered state seen at ovulation. Later in pregnancy, desquamation progressively increases until toward the end only a residue of the basalis is left. After birth of the young, the vaginal epithelium is rapidly restored and by the end of the first month is again of normal thickness.

The existence of the phenomenon described in the preceding paragraph makes possible a demonstration of the activities of ovarian hormones. Dr. Hartman and Dr. Davis tested an animal whose ovaries had been removed a year previous and found that it had a very thin vaginal mucosa, such as is found in senile animals. They then gave this animal, for a period of two weeks, injections of amniotin and at the end of that time the vaginal epithelium was completely restored to the normal active type. In their experiments in this field, they have been able to add an adequate histological demonstra-

tion of changes which had been surmised from vaginal smears and also to completely correlate these with ovarian activity.

MENSTRUATION

In some experiments made by C. G. Hartman and M. W. Firor in which the hypophysis of preadolescent monkeys was removed in varying degrees of completeness, evidence has been obtained of an activity of the posterior lobe in causing menstruation. Where the hypophysis is entirely removed, they find that oestrin administration does not cause bleeding; but in one specimen where the anterior lobe was cleanly removed and the posterior lobe left intact, oestrin caused characteristic uterine bleeding. This introduces a new angle to the menstruation phenomenon. Since menstruation is primarily a vascular reaction, one might well expect it to be associated with the neuro-vascular posterior lobe rather than with the epithelio-secretory anterior lobe. But we are still in the hypothesis stage and more experiments are needed.

PROLONGATION OF PREGNANCY IN THE RAT

In my report of last year a description was given of Dr. Snyder's important experiments in which he showed that induction of a fresh crop of corpora lutea in the pregnant rabbit defers parturition throughout the life-span of the new corpora lutea, and that therefore parturition is the result of the cessation of the inhibition effect of the corpora lutea. Following his lead, Dr. J. L. King and Dr. E. C. Hoopes of the Department of Physiology in Goucher College have tried similar experiments in rats and have been able to demonstrate that a single injection of 75 rat units of human pregnancy-urine extract given on the 19th or 20th day of gestation will prolong the pregnancy 3 or more days. The fetuses remained alive and continued to grow 2 to 3 days beyond the normal degree of maturity.

FETAL PHYSIOLOGY

The academic year 1933-34 was spent by Dr. L. B. Flexner as a guest in the laboratory of Professor Barcroft, Cambridge, England, with whom he participated in a series of studies of the conditions of respiration and cardiac activity in the fetus. Dr. Flexner brought back with him techniques applicable to fetal physiology which promise to be of considerable help to us in a field in which our group has thus far had little experience. Working with goat fetuses they undertook the problem of explaining how it is that the blood returning from the placenta to the fetus, up to the 19th week, has a higher oxygen pressure than that returning to the mother. Since the fetal circulation and the maternal circulation come into intimate contact in the placenta, it would be expected that they would emerge in equilibrium and that the oxygen pressure and hemoglobin content in each would be the same. In a series of tests extending from the 10th week till birth, it was found that the maternal blood had an increased hydrogen-ion concentration, which explains its relatively lower oxygen pressure as compared with the fetal blood. In addition it was found that the hemoglobin of the fetal blood diverges in its properties from those in the maternal blood. It would now be of interest

to correlate these findings with the changes in size and number of the red corpuscles at different stages.

These investigators also collected data relating fetal weight to placental weight at different times during pregnancy in the rabbit. A method was devised by them for obtaining blood from the uterine veins in the pregnant rabbit without injury to the nerve supply to the uterus and thus it was possible to record the oxygen saturation of the blood as it emerges from the uterus. It was shown that venous blood from the non-pregnant horn steadily retains 65 to 70 per cent oxygen, whereas that from the pregnant horn falls progressively in its oxygen to 30 per cent at parturition, returning, however, to over 70 per cent saturation within 24 hours after delivery. These figures give us an index of the utilization of oxygen from the blood as it courses through the walls of the pregnant uterus.

In another series of experiments, Dr. Flexner cooperated with Professor Barcroft and Dr. McClurkin in measuring the quantity of blood which passes through the fetal heart at various stages of development. Using fetal goats, kids and adult goats, they found that the oxygen used by the fetus, relatively to body-weight, increases after birth to four or five times the prenatal value. The quantity of blood which flows through the heart, as recorded by their cardiographic technique, is the same before and after birth, when related to body-weight. During the latter half of fetal life the ratio of the blood-flow through the heart to the weight of the body is fairly constant and amounts to 0.12 to 0.18 cc. per gram of fetus per minute. The oxygen used by the fetus also remains constant at about 0.0025 ± 0.001 cc. per gram per minute.

INFLUENCE OF ENVIRONMENT ON ENDOCRINE GLANDS

In another part of this report reference is made to the study of Dr. S. D. Aberle and Dr. W. Landauer on the inheritance of thyroid size in the chick. In another investigation they have studied the principal endocrine glands as affected in weight and structure when the animals during the first 8 months are raised under different conditions. They utilized the Frizzle fowl, which because of its ridiculous plumage is subject to an abnormal loss of body heat, and the results were controlled against Leghorns. The test animals were separated in three groups, each being subjected to a different living condition. One group was reared on a free range with standard mash food; another was reared in a heated house and also with standard mash; the third was reared in a heated house with 50 per cent of a vegetable fat added to the mash.

At the time of hatching, the adrenals, hypophyses and gonads of Frizzle chicks show no difference either in weight or histological structure from those of normal chicks. Under the experiments the adrenals showed very little difference from those of normal birds. The disturbance in the heat-regulating mechanism seemed to cause an increase of medulla-tissue at the expense of the cortex and possibly some increase in total weight. The hypophyses were the same as in normal control chickens. The testes, however, had a greater relative weight than those of normals. The difference was greatest in the least favorable environment and smallest in the most favorable one. Histologically the large size was accompanied by abnormalities in structure. The ovaries of Frizzles follow in the opposite direction and were always found

to have a much smaller average relative weight than those of Leghorns, and the average weight was least in the most favorable environment and greatest in the least favorable environment.

The most striking differences in the endocrine glands were those occurring in the thyroids, and this is obviously associated with the defective plumage and consequent loss of body-heat and acceleration of metabolism. In a very cold environment, the thyroid becomes exhausted and simulates a resting stage or maybe definite atrophy. In more favorable surroundings, the thyroid is able to respond to the demands of the organism and so is found in a state of hypertrophy and hyperplasia. If the conditions are most favorable, the thyroid structure is found to be normal. Thus the picture of the thyroid in the Frizzle fowl is greatly modified by the environment, but it is also true that the thyroids of newly hatched Frizzle chicks tend to be larger than those of normal ones. Furthermore in reciprocal crosses of Leghorn and Frizzle fowl, the thyroids are small in offspring from Frizzle females and normal males, and are large in matings of normal females with Frizzle males. These investigators therefore conclude that the Frizzle stock contains modifying genes which render the thyroid more responsive with hypertrophy in the face of unfavorable environment. It is to be added that reciprocal skin transplants between normal and Frizzle chickens gave results showing that the host organism has no effect whatever on the structure of the feathers.

HORMONES AND TUMORS OF THE BREAST

Evidence has pointed to oestrin, the female sex hormone, as the essential stimulant to the growth of mammary tissue in the normal development of the breast at birth and puberty. Some experiments have therefore been made by Dr. C. G. Hartman in cooperation with Dr. C. F. Geschickter and Dr. D. Lewis, in which they injected varying amounts of oestrin in male monkeys (*Macacus* and *Cebus*) and followed the effect on the mammary tissues. The best results were obtained by giving small daily doses over a long period. The breasts and nipples of macaques treated in this way were found to double in size, and when the tissues were examined microscopically it was found that the ducts were dilated and had increased in length. There was an increase in the number of layers of the epithelial cells and there was a characteristic proliferation of the supporting connective tissue. The perilobular stroma was also definitely increased. In one animal the condition was produced after castration. In another set of experiments in male monkeys with one or both testicles present, a similar, though less marked, increase in size of the mammary gland was produced by subcutaneous injection of the anterior-lobe-like hormone, prolactin, obtained from urine of pregnancy. The hypertrophy following the injections was clearly due to the stimulation of the testis, the interstitial cells of which produced the hormone causing growth of the breasts. The testicles were enlarged and there was a definite hyperplasia of the interstitial cells. In one case an hypertrophy of the prostate was induced, which resulted in urinary retention and dilatation of the bladder. In no case was enlargement of the breast seen when the hormone was injected in castrated monkeys.

The significance of these studies lies in the fact that the growth of the mammary glands thus experimentally produced are in all appearances identical with gynecomastia, female-like breasts which are occasionally seen in males, and which we may assume are hormonal in origin. The hormone in such cases may be supplied by ovarian tissue in hermaphroditic conditions, by chorionic tissue in teratomata of the testicle or it may arise from over-active interstitial cells of the testicle stimulated in turn by an anterior pituitary hormone.

Gynecomastia as a pathological condition closely resembles and appears to be related to vaginal hypertrophy and fibro-adenoma of the breast. It is therefore likely that these are similar to it in causation. A confirmatory test was obtained by making an assay of fibro-adenomas removed at operation and they were found to have a high concentration of oestrin, the guilty hormone. In all of the three types of hypertrophy mentioned, the histologic changes are those which occur normally in the breast during embryonic life and at puberty. To elicit such a response in the absence of ovarian or placental tissue is a clear demonstration of the nature of hormone stimulation required to produce the growth.

STUDIES OF THE NERVOUS SYSTEM

SEPARATION OF THE EXCITATORY FROM THE INHIBITORY FIBERS OF THE PYRAMIDAL TRACT

It is the usual experience that hemiplegia following hemorrhagic injury of the motor cortex is followed both by paralysis of the involved muscles and by a certain amount of muscle rigidity. It had also been noted that the degree of paralysis and rigidity varied from case to case, and this was not understood, because the pyramidal tract was presumed to be more or less homogeneous in its functions throughout its whole extent. By means of an instructive series of experiments, Dr. S. S. Tower has been able to give the reason for this. She has been able to show that the cortical area referred to sends down both inhibitory and excitatory fibers and that these in large measure part company in the hind-brain region above the level where the pyramids emerge from the pons. From that point the excitatory fibers extend down into the spinal cord as the crossed pyramidal tract, whereas the inhibitory fibers terminate in the bulbar portion of the hind-brain where by multiple connections they serve to regulate muscle-tone and coordination. Injury of the excitatory fibers results in paralysis, and injury of the inhibitory fibers results in rigidity, and thus the location of the injury determines the amount of mixture of the two resultant afflictions.

Dr. Tower's experiments were carried out on cats and consisted of cutting the pyramidal tract of one side at the level of the trapezoid body and this resulted in the permanent loss or decrease in function of the flexor activities of the opposite side of the body. After this condition had become adequately established, the motor cortex was stimulated and it was found that though no excitation of the muscles below the lesion could be induced there was, however, active response in the way of inhibitory activities, clearly proving that these two cortical functions are separated one from the other at some point above the level of the injury. In some of the animals, after establish-

ing the loss of flexor functions, the corresponding motor cortex was dissected off, and thus to the syndrome of the pyramidal lesion there was added a rigidity which before had not been present. Certainly for the most part, the rigidity elements leave the pyramidal tract above the level of the trapezoid body, and from that point down the fibers are almost exclusively excitatory. In establishing this Dr. Tower has made a long step forward in our understanding of one of the most important tracts of the brain and we are indebted to this investigator for a very carefully observed and detailed portrayal of the pyramidal-section syndrome.

Anatomical studies were made of the central nervous system of the animals used in Dr. Tower's experiments. The sections showed descending degeneration confined to the pyramid which had been sectioned and passing down in the large crossed and a small uncrossed bundle in the lateral columns of the cord. There was also some ascending degeneration in the lateral lemnisci of both sides and the medial lemniscus on the side of the lesion. The later is ascribed to the admixture of some sensory fibers making their way up along the pyramid. Strictly speaking, the pyramid is therefore a sensorimotor system, like its terminal field in the cortex.

NERVE-MUSCLE RELATIONSHIPS

In previous studies of the innervation of skeletal muscle, Dr. Tower found that for most muscles in mammals there is a simple type of innervation consisting of a myelinated somatic motor nerve which terminates with coarse ramifications in a typical hypolemmal ending. With such an innervation, a uniform response is obtained, namely maximal contraction. Different activities of muscles, tonic and phasic, are obtained through the ability of the central nervous system to send down impulses varying in frequency and number. There seemed to be no need for any accessory innervation and none was found, either sympathetic or of non-myelinated fibers of untraceable origin.

During the past year another series of experiments has been completed by Dr. Tower which follows as a corollary and confirmation of the above. In a series of cats, the innervation of one forelimb was partially or completely removed and in such a way that the somatic motor nerve was always cut (ventral root), and in some of them sensory and sympathetic nerves (dorsal root, root ganglion and sympathetic lesions) were also cut. After varying periods of time the animals were killed and fourth and fifth interosseous muscles were removed, weighed and prepared for microscopic study. It was found that cutting the ventral root alone established the complete picture of atrophy and degeneration of the muscle. When the sensory and sympathetic nerves were also injured there was no evidence of additional atrophy, degeneration or dystrophy whatever. It is therefore evident that the latter nerves do not participate in the innervation of these muscles, in the sense of exercising an essential or trophic control, and are not even an accessory in maintaining the integrity of the muscle fibers.

In following the changes which occur in skeletal muscle following denervation, it was found that an atrophy occurs first in which there is a reduction in the size of the muscle and its component fibers. The striations are still present and function appears still possible. Some months later the muscle

undergoes fibrous dedifferentiation until the muscle is replaced by tissue resembling something between scar tissue and tendon. The immediate reaction of muscle to denervation is limited to the nuclei and sarcoplasm, whereas the more highly differentiated myofibrillæ show no alteration until much later. This indicates that the nuclei and sarcoplasm are dependent upon the innervation and that the myofibril is not. This explains why contraction can be obtained in a muscle so long after it has lost its nerve supply. It is of further interest to note that in the process of atrophy, the nuclei proliferate whereas the sarcoplasm disappears. The aggregation of nuclei around the motor end-plate quickly respond to disintegration of the nervous tissue and also all the nuclei throughout the length of the fiber. The question is raised whether these unconnected and seemingly inactive nuclei may not serve as a conducting mechanism within the nerve fiber toward the excitation of the contractile mechanism, but evidently dependent on the intact nerve. Dr. Tower's study of the histology of the degenerating muscle fiber and the recovery of fibrous relics when reinnervated are definite contributions to the understanding of nerve-muscle relationships.

AUDIO-ELECTRIC PHENOMENA IN DEAF ALBINO CATS

In a series of albino cats, Dr. H. A. Howe has an experimental animal in which the only abnormality of the organ of hearing lies in the cochlea. For the most part the defects are found in the organ of Corti which is more or less degenerate. In none of the cases where the cat was clinically deaf could the electrical effect (Wever and Bray phenomenon) be obtained, although in normal cats it can almost invariably be demonstrated. The evidence appears conclusive that the integrity of the organ of Corti and the activity of its sensory cells are essential for the production of the changes in electrical potential in the auditory nerve. The increasing mass of data on the physiology of the ear has been one of the outstanding products of research activity during the past few years, and in this work the Otological Research Laboratory of Dr. Crowe and his associates have played a large part.

INNervation OF THE AORTIC PARAGANGLIA

During the past year Dr. G. Muratori, Assistant in the Anatomical Institute of the University of Padua, under Professor Terni, has been a guest of the laboratory as Rockefeller Fellow. His study of the innervation of the walls of the aorta and the connections between the aortic fibers and the paraganglion body has been published during the year. The investigation was done in Padua, and in bringing his experience to our laboratory Dr. Muratori has been able to assist in similar studies that have been made by Dr. Boyd and are now in preparation for publication.

SYMPATHETIC NERVE CONTROL OF THE URINARY BLADDER

A study of the nerve mechanisms of the bladder has been completed by Dr. O. R. Langworthy, Dr. D. L. Reeves and Dr. E. S. Tauber. Various aspects of the bladder activities are matters of considerable clinical importance, and through animal experimentation (cats) they have been able to define more clearly the control exercised by the sympathetic system, especially

with respect to intravesicular volume and pressure. For the first time we have accurate data on the effects upon bladder pressure and volume resulting from removal of the sympathetic nerve supply. They find that on cutting the sympathetics the viscus loses the normal ability of holding varying quantities at approximately the same pressure. The muscle becomes less irritable and the fluid is held at a lowered pressure. On the other hand the emptying reflex becomes more forceful and the quantity of fluid required for reflex micturition falls steadily during the first few days after sympathectomy. The sympathetic stimuli are thus found to exert two opposing forces; one produces a contraction of smooth muscle-fibers at the base of the bladder and so some rise in pressure, the other inhibits the detrusor muscle. The latter, the emptying muscle, is innervated by branches from the sacral nerves (parasympathetic). The sphincter activity was not especially studied, but there seemed to be no individual activity of the sphincters separate from that of the vesical musculature; the activity of the sphincters is merely related inversely to the activity of the detrusor muscle. On the whole it was concluded by these investigators that the sympathetic fibers are not essential to normal micturition. In the animals where they are well developed, they serve as an inhibitory control over the detrusor muscle and this enables the animal to increase the interval between micturitions. Where the parasympathetics are damaged, this becomes a liability and cutting of the sympathetics makes expulsion of urine more efficient.

ANATOMICAL STUDIES

ANATOMY OF THE HAND

A comparative study of the fin plan of *Sauripterus* (Devonian ganoid) and the anterior appendage of *Eryops* (Permian amphibian) has led Professor A. Brazier Howell to interpret the fin of the former as functioning as both a fin and a limb, its postaxial or ulnar border coming in contact with the ground. It was first necessary for the appendage to rotate to a horizontal position with the flexor surface down, and then it was necessary to provide it with joints. In this process the carpus was apparently formed by splitting the fin carpal cartilages of *Sauripterus* into transverse rows, accompanied by some redistribution of the proximal cartilages and displacement of others, as the radius and ulna became equal in length. In this process what is now the first metacarpal in mammals was originally a carpal bone. Mr. Howell concludes that the primitive hand was pentadactyl and that a prepollex and post-minimus never occurred as actual digits.

A contribution to the comparative morphology of the hand and foot in primates has been made by Dr. C. Midlo who, as National Research Council Fellow, made a study of the material available in Dr. Schultz' large collection. This was supplemented by primate material from other nearby collections. In all a total of 106 primates was studied. Measurements were made of the palm, sole and digits, and a series of drawings representing the palmar and plantar surfaces of the hands and feet of each available genus. Based on these data, tables were prepared giving the proportions between palm length and sole length and the first and third digit. Also a table was made

giving the digital formulæ for a large number of representative primate species.

From this study one can appreciate the markedly specialized structure of the prosimian hand and foot, which deviate much more from the primitive mammalian type than do the hands and feet of higher primates, and especially in the first and second digits. In general it is found that marked specialization is associated with marked brachiating habits. It is of interest to note that man has a more primitive hand and a more specialized foot than any of the Pongidæ. The accurately executed drawings which are published with Dr. Midlo's study will be of great value to all students of the comparative anatomy of the hand and foot.

RELATION OF AGE AND DENTITION IN PRIMATES

Bringing together his observations extending over many years, Dr. A. H. Schultz has been able to present a comprehensive study of the eruption, attrition and decay of the teeth in monkeys and apes. In a small group of macaques he has been able to follow the history of the teeth in individuals of known ages from birth to early maturity; also he has studied over a limited

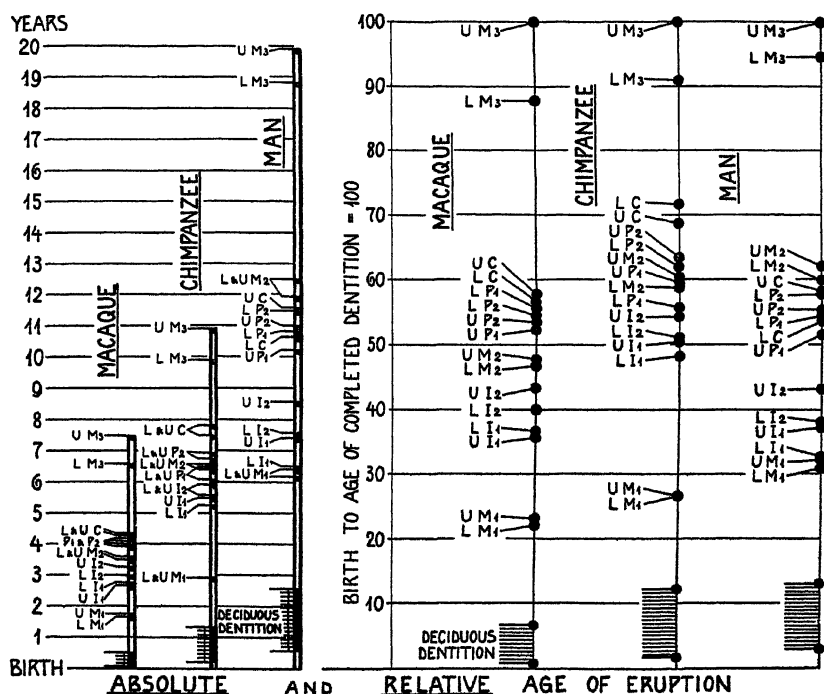


FIG. 1.—When adjustment is made for their life-span, tooth-eruption is much the same in the macaque, chimpanzee and man. The diagrammatic representation shown here of the absolute and relative ages of eruption of the various teeth was based by Dr. A. H. Schultz on averages from a large number of observations. Abbreviations: C, canine; I, incisor; L, lower jaw; M, molar; P, premolar; U, upper jaw.

period a few specimens of living chimpanzees. The bulk of his data, however, is derived from examination of approximately three thousand primate skulls, over three hundred of which were from gorillas. The completeness of his age data on the appearance of the deciduous teeth and their replacement with permanent teeth will be of value to all those who are concerned with age problems in the primates.

The age at which the deciduous and permanent dentitions erupt is shown in figure 1. It will be noted that not only in man but also in the chimpanzee and macaque there exists a relatively long resting period before the eruption of the last molars. It is of interest to note that in many primates, including man, the canines of males erupt slightly later and often more slowly than those of females. Also, with comparatively few exceptions, the teeth of the lower jaw erupt before the corresponding teeth of the upper jaw, especially in case of the molars.

Deviations from the normal arrangement of the permanent dentition have been studied by Dr. Schultz in previous investigations and have been referred to in these reports. It should be pointed out that attrition and caries, which Dr. Schultz has studied extensively, furnish us with important data needed in the interpretation of age and disease changes in the dentition of man. Caries and alveolar abscesses are extremely rare in deciduous teeth of monkeys and apes, and in the permanent teeth these conditions become more frequent in the adult than in the young and increase in frequency in the old. Age is thus a factor in these pathological processes. Carious teeth vary in frequency in different types of primates. It is of especial significance that in over half of the cases of caries, the cavities occur in the same teeth on the right and left side of the jaw concerned. In other words its incidence involves bilateral symmetry and hence embryonic constitution must be regarded as a predisposing factor. Caries appears to affect the first incisor and the first molar more frequently than any of the other teeth and it is found more often in the upper than the lower jaw.

Regarding attrition and loss of teeth and alveolar walls, it is found by Dr. Schultz that this becomes very prevalent in simian primates of old age. Not only in man, but in apes and monkeys as well, the dentition begins to deteriorate before the termination of the normal life span. In general it appears to be more common in the higher than in the lower primates and it would seem that the prolonged life span of anthropoid apes and man is not accompanied by a corresponding increased durability of the dentition. Like the eyes and the hair, the teeth fail us while the body otherwise may be going strong.

At this place mention may be made of the study by Dr. T. W. Cook, who has studied the development of the jaw and the dental alveolæ in the human fetus. He has been able to dispose of the hypothesis that the growth of the brain takes away energy from the lower alveolar process during the early stages. It had been explained that the lower border of the mandible is also retarded by growth of the brain and thus as compared with the alveolar process it later comes to project forward, thus producing a chin. Dr. Cook has been able to demonstrate the chin is present before the eighth fetal month, long before the time of the supposed repression.

Another study from the dentists' viewpoint concerns the incidence of dental caries in our colony of macaque monkeys. This has been investigated by Dr. H. Klein. He examined 62 animals with explorer and mirror and found that, in 30 monkeys with third molars erupted, 7 showed dental decay, mostly associated with wear. Of 32 animals in which the third molars had not yet erupted there was only one showing dental decay. This was in the lower milk molars.

STRUCTURE OF THE PRIMATE KIDNEY

From a study of the morphology of the kidney in lemurs, monkeys and anthropoid apes, Dr. W. L. Straus jr. finds that with the exception of some specimens of *Ateles* the kidneys of all of them are unipyramidal though showing some differences as to the form of the papilla. Of the primates it is only in man and in some examples of *Ateles* that the multipyramidal kidney is found. The phylogenist is going to have some difficulty in explaining this unique position of man and this strange type of kinship with the spider monkey. Dr. Straus points out that the kidney of man by no means represents the extreme of lobulation among the mammals. There are many mammals, larger and smaller, which exhibit a far greater degree of subdivision. The presence of true primary internal renal lobulation in the two forms *Homo* and *Ateles* are regarded by him as a product of convergence, and it seems likely that we will hear more about convergence as time goes on.

FEMALE GENITAL TRACT IN MARSUPIALS

Based on gross and microscopic observations on the female genital tract in three genera of living *Cenolestids*, Dr. J. S. Baxter has analyzed the homologies of the lateral vaginal canals. The material on which this study was based had been secured through the resourceful efforts of Dr. R. K. Enders. The relationships of the various marsupial forms have presented many phylogenetic difficulties and the problem needs approach from all aspects. Dr. Baxter has contributed the evidence to be obtained from the genital tracts of this little-known group of marsupials, *Cenolestes* and its allies *Orolestes* and *Rhyncholestes*. He finds that the genital tract in these forms, though highly specialized, is mainly Didelphyd in character. Dr. Baxter points out that, inasmuch as *Cenolestes* does not agree very closely with any one genus of the South American Didelphyds, the possession of Didelphyd characters by its genital tract must be explained as the result of convergent development.

STUDIES IN INHERITANCE

INHERITED REDUCTION IN TEETH

In a previous Year Book (1931) mention was made of a study by Dr. A. H. Schultz of the elimination of incisors in man varying from a decrease in size to complete disappearance. He found that it was not a particular variation that was inherited but instead a tendency to vary in the direction of a reduction, and the inheritance was effected in different manners in different families. Since then Dr. Schultz has been able to record a new pedigree in which the tendency to reduction in the incisors occurs simultaneously with a tendency to reduction in the third molars. It had been well established

that the trend toward reduction in the number of permanent teeth usually occurs at one end or the other of the dentition, involving either the incisors or the last molars. It is now shown that the reduction may occur in the same individual at both ends. In addition to isolated specimens Dr. Schultz has now added this pedigree in which the absence of the third molar is recorded in four successive generations and in which the individuals showed in varying degree the tendency toward elimination of the upper lateral incisors. In some cases only one of the two upper laterals was reduced in width and in height; in one case both upper laterals were vestigial and in two cases they were completely lacking. It is of interest to add that in the last generation all four upper deciduous incisors had been present, and were therefore not *participes criminis*.

GENETICS IN PARAMECIUM

It was found by Dr. C. F. DeGaris that double monsters can be produced in *Paramecium caudatum* through inhibiting cell division by reduction of temperature or by cyanide vapor. Such monsters when so produced have the power of conjugating with free individuals of the same clone, either one or both components being so engaged. In order to effect conjugation it was found essential that both monsters and the free individuals should be derived from lines ready for conjugation. Dr. DeGaris has thus devised a means of identifying, or tagging, the members of one line in crossing with another line. An advantage in double monster mating is derived from the retarded physiological state, particularly suspension of nuclear activities, so that a monster in a conjugating line will still take part in conjugation for two or three days after all free individuals of the same line have ceased to mate. Another advantage arises from the fact that the difficulty of assortative mating may in this way be surmounted, and long may thus be mated with short. The use of double monsters in effecting crosses between pure lines of paramecia has been experimented with by this investigator for a number of years and recently it has been extended to crossings of two species as described in the next paragraph.

Utilizing the fact that the monster condition offers a definite and simple means of identifying the participants in a given cross, Dr. DeGaris attempted crossings between *Paramecium aurelia* and *P. caudatum*. After inducing monster formation in the caudate line, he introduced these monsters into a conjugating population of *P. aurelia*. The caudate monsters readily acquired aurelian mates and conjugation occurred and the pair could be isolated. The mates remained adherent to the monsters for a number of hours. Some did not become disengaged at all and by the second day underwent cytolysis. The mates that became free invariably died on the second or third day after conjugation. The caudate monsters lived for an average period of six days after conjugation, which is fairly comparable to the life of monsters which have not conjugated. A striking difference from the latter, however, was found in that none of the conjugant monsters gave off any free cells after conjugation, nor was there any sign of growth or change in configuration. Though crosses between these two species may be made, they are invariably lethal to *P. aurelia* and they are not without harm to *P. caudatum*. We are

now faced with the interesting problem of learning whether this rests in nuclear factors or is a matter of incompatibilities of cytoplasm. The cause of genetics has poor prospects in this direction.

SEX AND THYROID WEIGHT

Dr. S. D. Aberle, formerly of Yale University School of Medicine, in collaboration with Dr. W. Landauer of the Storrs Agricultural Experiment Station, has been able to demonstrate a sexual difference of thyroid weight in newly hatched chicks. These investigators determined the actual and relative thyroid weight in some 900 newly hatched chicks, belonging to six different groups. Within each group the actual and relative weight of the thyroid was greater in females than in males. In the whole material the average relative thyroid weight amounted to 12.8 ± 0.19 mg. in males and to 14.4 ± 0.20 mg. in females. On July 1, 1935, Dr. Aberle took over a responsible position in the Indian Service of the Government. She still retains, however, her association with the Division of Animal Biology and the Division of Historical Research of the Carnegie Institution.

BEHAVIORAL STUDIES

MACAQUE BEHAVIOR DURING FIRST YEAR

In a cooperative study with Dr. Hartman, Dr. J. P. Foley jr. has reared and studied a new-born macaque in complete isolation from its mother and other members of the species. A report has been completed of a one-year period under those conditions. The object of the experiment was primarily to demonstrate its feasibility. Since the infant did survive and develop in a manner exceeding all expectations, the way is now open for the utilization of infant macaques in a comprehensive investigation of the developmental nature, origin and modifiability of organic behavior.

An important product of the experiment was the successful working out of a dietary regime that enables one to remove the baby from its mother on the third day and rear it as a strong healthy animal. In his account Dr. Foley gives in detail the feeding schedule and the foods found best adapted month by month.

Dr. Foley's observations while intended merely as an exploratory survey fall under three general headings. The first includes physical development, including general appearance, weight, body proportions and eruption of teeth. The second group of data cover sensorimotor and simple behavioral development including records as to time of functional development of the various primary sensory perceptions, reflexes and other simple motor reactions. Among these may be noted the following: visual receptivity and eye reflexes; audition; olfactory, gustatory and tactile stimulation; scratch reflex and grasping reflex; locomotion, climbing, jumping, play behavior, manipulation, and use of cheek pouches. Finally the third group of observations are those on the development of more complex behavior patterns, such as eating methods, vocalization, use of hands, thumb sucking, emotional behavior, reactions to other animals and to his mirror reflection. It was found that throughout the first year there was no indication of "grooming"

behavior or "autogrooming," that is picking the hair. Apparently when reared in isolation and free from parasites, this does not occur, and it would therefore seem likely that such behavior is not innate nor structurally conditioned. Throughout the year there was no behavior observed that could be regarded as influenced in any way by premonitory sex stimuli.

SEX BEHAVIOR

From the fact that the menstrual cycle and the day of ovulation are regularly determined with precision in a considerable number of female macaques in Dr. C. G. Hartman's colony, advantage of it has been taken by him and Dr. J. Ball to correlate with these events certain aspects of sex behavior and sex desire, determined in a quantitative way. In eight females studied from three to eight months each, tests were made three times a week, the sexes being kept segregated except during the tests. Three behavioral units which could be accurately recorded were selected for measurement of sex desire: (1) "presenting"; (2) attempts to attract the males attention by threatening an outsider; and (3) going toward as against going away from the male. The scores obtained on this objective basis when plotted relative to the days before and days after ovulation give a curve which in typical cases rises high before ovulation and falls thereafter. Differing from lower mammals, however, the drop is not so complete as to amount to consistent refusal to mate.

In order to determine if the uterus and vagina are the sources initiating sex behavior, Dr. J. Ball has removed these organs in young rats, leaving the ovaries and Fallopian tubes in place. Four such animals formed the basis of her experiments and upon being placed with males exhibited typical sex activity. This demonstrates that nerve impulses or other effects arising from these organs are not essential for the production of the condition called heat, during which period the animal responds with behavior that can not at other times be elicited.

DEPARTMENT OF GENETICS¹

A. F. BLAKESLEE, ACTING DIRECTOR

DATURA INVESTIGATIONS

A. F. Blakeslee, A. G. Avery, A. D. Bergner, S. Satina, J. L. Cartledge and
J. T. Buchholz

TIL SPECIES PROBLEM

In the *Datura* investigations, continued emphasis has been put upon the species question and related problems. A total of 575 races of our standard species, *Datura stramonium*, from widely separated places throughout the world have been tested by crossing with the standard Line 1 of this species and studying the chromosome connections in pollen mother-cells in the hybrids. By this method, in addition to the four main prime types assumed to have been derived from Line 1 by segmental interchange of chromosomes, two new prime types have been discovered from nature. One of these from northern Argentina has the two chromosomes 15·23 and 16·24, not hitherto found in nature, in place of the 15·16 and 23·24 chromosomes of our standard Line 1. The other new chromosomal type, obtained from Mexico, has the chromosome 11·21 which appears to be the same as one of the modified chromosomes in Prime Type 3. It has also the chromosome 4·22 which has the same ends as one of the chromosomes in P.T. 4 and, in addition, has a new chromosome 3·12 which may have been derived by crossing over between the chromosome 12·22 of P.T. 3 and the chromosome 3·21 of P.T. 4 in a hybrid between these two prime types which are known to occur in Central America.

Other species of *Datura* have been similarly tested, though with fewer races than has been possible with *D. stramonium*. Four prime types have been found among 32 races of *D. metel*, three among 19 races of *D. meteloides*, two among 23 races of *D. innoxia*, two among 2 races of *D. leichhardtii*, two among 3 races of *D. quercifolia*, and two among 11 races of *D. ferox*. In all these species, prime types may be interpreted as having arisen by shifting of ends of chromosomes through segmental interchange. As pointed out in earlier reports, species differ one from another by just such changes as have been found to separate prime types within individual species.

The method of analyzing chromosomal differences between species involves hybridization with races and species in which the chromosomal constitution has been determined. Since certain species cross with difficulty, a study has been begun of the crossability between species. The pollination *D. stramonium* × *D. metel* sets capsules but only abortive seeds are produced. Miss Satina has found that fertilization in this case actually takes place, but that growth of the 2n embryo ceases after the formation of at most eight cells. The 3n endosperm may form over a hundred cells. What causes the cessation of growth at an early stage in embryo and endosperm is as yet unknown.

Crossability between species involves the ability of pollen of one species to grow in the style of the other. This problem is being investigated by Dr. Buchholz. All the 90 pollination combinations have been tested with ten

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species of *Datura*. Reciprocal pollinations may be decidedly different in the rate of pollen-tube growth and the percentage of burst pollen tubes in the style. In about 20 out of the 90 species combinations, the bursting of pollen tubes is so extensive that crosses can not be expected. In general the pollen tubes of species with long styles grow at a more rapid rate than those of short-styled species.

This past year by proper breeding procedure we have synthesized a new pure-breeding chromosomal type which has the formula $2n - (1\cdot2)_2 - (11\cdot12)_2 + (1\cdot11)_2 + (2\cdot11\cdot12)_2$. Since this type has an excess material, two doses of the $\cdot 11$ half chromosome, it is similar in appearance to the secondary trisomic type $2n + 11\cdot11$ which can not breed true.

MUTATION IN AGING SEEDS

Dr. J. L. Cartledge, working under a grant from the American Philosophical Society, has continued his studies on the increased rate of mutation from aging seeds, using the occurrence of aborted pollen grains as an index of the mutation rate. The seeds mentioned in the last annual report, buried in the soil under a dwelling for 22 years, showed very little increase in mutation rate over the rate found from fresh seeds. The high mutation rates previously found from seeds stored in the laboratory seem, then, to be conditioned by other factors than age alone. In cooperation with Dr. William Crocker and Miss L. V. Barton of the Boyce Thompson Institute, who have cared for the treatment of the seeds, the effects have been studied of heat treatment at controlled moisture levels. The effects of these treatments include (1) a progressive delay in germination of the seeds with increased duration of treatment, (2) killing effect in longer durations at high temperature, and rapid killing at higher moisture levels, (3) production of up to 90 per cent abnormal growth habit types as a direct effect of treatments and (4) increases in mutation rates. No mutations were found in 321 control plants, while 16 mutations (4.5 per cent) occurred in 372 plants from seeds held at 5 per cent moisture and 80° C. from 14 to 18 hours. It would appear from these experiments that high temperature may be an important factor in inducing mutations in aging seeds.

POLLEN AN INDEX OF CHROMOSOMAL CONSTITUTION

The condition of the pollen may be used in several ways as a short-cut to a determination of the chromosomal condition. Last year, in cooperation with A. D. Shamel, Dr. Cartledge found that two large-fruited varieties of Bartlett pears which had originated as bud sports in Shamel's cultures were probably tetraploid, as indicated by size of the pollen grains. This spring an examination of chromosomes in young flower buds of this material has shown that both of these varieties have about the tetraploid number of chromosomes, thus confirming the judgment made a year previous from observation of pollen that these two bud sports must be tetraploid.

GENES

From earlier radiation treatment and from the aged and heat-treated seeds we are obtaining an abundance of new genes, many of which will be

of use as markers with which to tag the chromosomes in breeding experiments. Mutations which affect vital processes, such as behavior of chromosomes, are of especial interest in relation to evolution. Only one such mutation need be mentioned. A gene has been found which is responsible for formation of compound pollen grains. Dr. Bergner finds that this gene causes partial or complete failure of cell division after the second telophase. At the time of dehiscence of the anthers, at least 65 per cent of the pollen grains have aborted and about 15 per cent of the good grains are compound in nature, containing from 12 to 48 chromosomes, usually in from two to four nuclei. This gene is carried through the pollen as well as through the egg.

Progress is being made in locating genes from our collection in the proper chromosomes. Of some interest is the group of a half dozen genes in the 11·12 chromosome. From trisomic ratios it has long been clear that the genes for "inermis" (*in*) and "early" (*e*) were in this chromosome but they assort independently of each other in inheritance. The genes *e*, *sk*, and *sf* form a single linkage group independent of the gene *in*, which from linkage alone would be considered in another chromosome. This last year we have found that the gene *zg* gives linkages with both *in* and the *e*, *sk*, *sf* group. The locus of the gene *zg* is not in the 11·12 chromosome, however, but is closely bound up with the Prime Type 34 which was formed by segmental interchange between the 11·12 and the 23·24 chromosome which carries the dominant allelomorph *Zg*. Crossing over between the gene *in* and the chromosomal complex containing the gene *zg* apparently parallels the condition in *Oenothera lamarckiana* which always is heterozygous for two chromosomal complexes. The condition in *Datura* may be of interest to those students of *Oenothera* who seem not to realize that crossing over can take place between chromosomal complexes to such an extent as to give independent assortment.

CHROMOSOMAL BEHAVIOR OF FEMALE GAMETOPHYTES

Most of our information about the behavior of chromosomes at reduction has been obtained from the divisions in pollen mother cells which are easily prepared by the aceto-carbimide method. The behavior of chromosomes in the female gametophyte, which is of more importance for the transmission of chromosomal abnormalities, has been generally neglected because of the more tedious method of cutting sections. Miss Satina has started an investigation of this neglected field and has already made valuable discoveries, among which is the work on incompatible interspecific hybrids already mentioned. A study now in progress on the female gametophyte of triploids is giving results which tend to explain the discrepancy between the theoretical proportion of chromosomal types in the offspring of triploids and those actually obtained. In all the five divisions of female gametophyte, lagging chromosomes have been found and their elimination would tend to bring about the reduction in number of chromosomes in the egg which is necessary to account for the large proportion of diploids in the offspring of 3n parents.

THE GENE

M. Demerec and G. A. Lebedeff

GENETIC LOCI IN SALIVARY CHROMOSOMES

Heitz's discovery that the structure of giant chromosomes of salivary glands is a constant feature and Painter's finding that that structure can be correlated with the loci identified by genetic methods gave to *Drosophila* geneticists an important tool for use in their work. Salivary chromosomes, which are over 150 times as large as chromosomes of sexual cells, show about 2700 distinct bands, according to Bridges' estimate, which fairly closely agrees with the estimate made by genetic methods for the total number of loci (see last year's report). This observation opens the question of whether or not individual bands represent individual loci, *viz.* whether or not the individual bands are formed through the activity of genes located in a particular locus of a chromosome. An answer to this question should bring us a step closer to the possibility of a physical analysis of the gene. All our present knowledge about the gene has been collected through indirect methods by studying the effect it produces on the organism.

The material which has been accumulated during the past few years for our studies of the action of the gene on the organism is particularly well suited for identification of loci in the salivary chromosome. A large part of this material consists of deficiencies in which a short section of a chromosome is missing. Since the chromosomes of *Drosophila* females are present in pairs, and since in salivary glands both members of a pair are not only joined lengthwise but their homologous bands are also paired with each other, the absence of any section in one member of a pair can readily be identified by the presence of corresponding bands in the normal member. If the deficiency is short so as to involve only one band cytologically and one locus genetically or if several partially overlapping deficiencies are available, it is possible to determine which of the bands stand for which of the genetic loci. It is advisable to base any conclusion on the analysis of several deficiencies covering the same region, since otherwise it is very easy to make mistakes.

In our collection, 61 deficiencies dealing with 13 regions of the X-chromosome are available. Of these, 15 have been cytologically analyzed. Since this analysis in certain cases at least is still only a preliminary one and requires rechecking by use of additional material, only the results of the analysis of the Bar-forked region will be referred to at this time. For that region there are available in our collection 17 deficiencies, 5 of which have been studied through salivary chromosomes. The results of these studies indicate that the deficiency for the genetic locus forked is always connected with the absence of the band named 15F1 by Bridges. Breeding tests showed that the absence of this band has a cell-lethal effect, *viz.* that even a few cells carrying such a deficiency were not formed. Although the genetic locus represented by the adjacent band (15F2) is not yet known, it was possible to determine that a deficiency for that band has a semilethal effect, *viz.* that the flies carrying that deficiency are able to live but are weaker and appear in smaller numbers than expected. The genetic locus for the next

band (16A1) is also not known; a deficiency involving that band only has a cell-lethal effect similar to the deficiency for 15F1. The band representing the bar locus has not been identified as yet, but indirect evidence indicates that it is located between bands 15F2 and 16A1.

Thus with the help of salivary chromosome studies, it is possible to carry the analysis of the action of the gene on the organism much further than through genetic studies alone. By combining both methods it is possible to analyze the action of the loci which are not known genetically.

THE 260-2 DEFICIENCY OF *DROSOPHILA MELANOGASTER*

A detailed study has been completed of the deficiency called 260-2. This deficiency affects the yellow end of the X-chromosome. Genetically it includes yellow and achæte loci and cytologically it includes 8 salivary chromosome bands, *viz.* the bands 1A1 to 1B1.

This deficiency is lethal to the whole fly, but it is not cell-lethal, *viz.* a few hypodermal cells homozygous for the deficiency are able to exist. Experiments were completed to determine the stage in embryonic development at which this deficiency kills the flies. Counts made on eggs showed that the eggs carrying the deficiency hatch, counts made on larvæ revealed that an unexpected number of them die, and counts of pupæ and hatched flies showed that the expected number of pupæ develop into flies. These results indicate that the lethal effect of the 260-2 deficiency comes during the larval stage of the development. To determine the exact stage at which the deficient larvæ die, larvæ were examined at 12-hour intervals and the death rate determined each time. It was found that during the larval stage, which lasted about 110 hours, the death rate was very high between 36 and 60 hours. It is thus evident that larvæ homozygous for the 8-band deficiency in the yellow region of the chromosome are able to live for about 60 hours. This region of the chromosome, therefore, is strikingly different from the forked region reported above in which out of loci represented by three adjacent bands two produce a cell-lethal effect when deficient.

The 260-2 deficiency is also interesting because it confirms the observation made by Ephrussi that a deficiency for the yellow locus produces a yellow phenotype. By the use of an autosomal minute, which stimulates the somatic segregation of X-chromosomes, it is possible to produce on females large patches of tissue homozygous for 260-2 deficiency, *viz.* of the nulo yellow constitution. A comparison of the yellow color in such patches with the yellow color of the original yellow mutation indicates that these two colors appear identical.

EFFECT OF X-RAYS ON HEREDITARY CHANGES

It is well known by now that X-rays produce two types of hereditary changes, *viz.* chromosomal rearrangements and changes in genes. Data are not available, however, on the relative frequency of these changes. Such data would contribute toward the solution of problems as to the nature of these changes and also would add to our knowledge concerning the action of X-rays. The following experiment was, therefore, arranged in order to obtain such data. X-chromosomes of one-hundred sperms treated with

about 2500 r-units were tested for lethal and visible gene changes and for chromosomal rearrangements. Out of 100 chromosomes tested, 11 had lethals, 2 visible changes making a total of 13 gene changes; 5 had chromosomal rearrangements and 5 had both chromosomal rearrangements and lethals occurring simultaneously. Of a total of 18 gene changes observed, 13 occurred independent of chromosomal rearrangements, and out of 10 chromosomal rearrangements, 5 occurred simultaneously with gene changes, suggesting a connection between the occurrence of chromosomal rearrangements and gene changes. This indication is strengthened by the data obtained from the salivary chromosome analysis of 10 simultaneous chromosomal rearrangements and gene changes taken from our collection of deficiencies. In 8 out of 10 cases the breakage in the chromosome occurred at approximately the same place at which the gene change occurred. In two other cases the gene change under observation was some distance from the place of the chromosomal rearrangement. This finding shows conclusively that there must be a connection between gene changes and chromosomal rearrangements. It makes probable the possibility that in the case of simultaneous changes the chemical reaction which accompanies a gene change affects the chromosome thread which happened to be nearby in such a way that the two threads fuse. When the chromosomes separate again, the threads may break at the fused place, producing a chromosomal rearrangement. It seems possible that such a mechanism may be responsible for the occurrence of a great majority of chromosomal rearrangements. As shown by Timofeeff-Ressovsky, gene changes which have a very slight effect on the organism are about twice as frequent as lethals and visible changes. To detect such changes a special technique is required which has not been used in our experiments. In addition there are undoubtedly gene changes which can not be detected at all. In the case of chromosomal rearrangements, therefore, where no simultaneous gene change was observed, it may be possible that such a change really occurred but has not been detected.

INHERITANCE OF HERMAPHRODITISM IN *DROSOPHILA VIRILIS*

Genetical studies of hermaphroditism in animals have been obscured by the effect of the endocrine system. It is therefore fortunate that hereditary hermaphroditism has been found in *Drosophila* which is genetically a well-known organism, and in which the endocrine system is probably not present. As was reported last year, a gene called intersex (ix) was found in *Drosophila virilis* by Mr. Lebedeff, which gene stimulates the development of the male reproductive system in homozygous females with the ultimate result of sex reversion. After a few generations of selection, three lines (designated 1, 3 and 4) were isolated, producing morphologically different types of sex intergrades. In type-1 the male reproductive system is slightly developed and it resembles normal females. Type-3 is male-like, though it retains the female shape of the abdomen and possesses a pair of underdeveloped ovaries in addition to the pair of undersized testes. Type-4 has completely reverted males, which are sterile. In addition, through breeding these, there is a type-2, the hermaphrodite, in which the reproductive system of both sexes is present, including external genitalia, genital ducts and gonads. This

year Mr. Lebedeff's studies were conducted in three directions: (1) Location of the *ix* gene in the chromosome and the study of the genetical relation between various morphological types of sex intergrades; (2) study of the development of the gonads in various types; and (3) histology of the gonads in adults of various types.

The *ix* gene was found to be located about seven units from the third chromosome terminal gene garnet. It was also found that when the *ix* gene is not affected by sex modifiers, it causes a reversion of homozygous females into males. The other morphological types of sex intergrades are the result of incomplete reversion brought about by modifying genes. It is assumed that these modifiers determine the time of activity of the *ix* gene. The presence of one dominant modifier accounts for the appearance of type-3 intersexes. The genetics of type 1 and 2 is not completely worked out as yet. Of the other sex modifying factors could be mentioned one which causes the twisting of the male external genitalia, and which behaves as a dominant in type-3 and as a recessive in type-4, and a dominant modifier which suppresses the action of the *ix* gene. It is hoped that further studies in that direction will increase our knowledge of the mechanism of sex determination.

The development of gonads in type-3 was studied. With the technique employed, only the testicular part of the ovo-testes was traced from 2-3-day old larvæ to the adult stage. In the early larval stage the gonads can hardly be differentiated from the testes of normal male larvæ of the same age. In about 3-4-day old larvæ a peculiar distribution of spermatogonia and spermatocytes can be seen. After that stage a process of disintegration begins, leaving almost no cells in the testes of adults. With the new method in use, we hope to find out whether or not two sets of gonads in type-3 develop the two different sets of imaginal discs. Studies of gonads in adults of type-3 reveal that there are two pairs of gonads which are always attached together, presumably by means of overdeveloped connective tissue. There is, however, no inner connection between male and female gonads. The testicular part is almost completely devoid of cells. In the ovarian part of the gonads, two types of cells are found: small cells and larger ones, which have some resemblance to the gonial cells and auxocytes of both sexes. The same is true for the cells found in the testes of adults of type-4, although the shape of the testes appears to be normal.

GENETIC STUDIES

By Guest Investigators

STUDIES ON GROWTH AND SEX IN INVERTEBRATES

During the past year a survey has been made by Dr. Banta, Dr. Brown and Miss Wood of the past and current work as it relates to crowding of the mothers and quantity of food as factors in the control of sex of offspring of *Moina macrocopa*. Their publication brings convincing evidence of the effects of crowding as a major influence in the control of sex in this organism.

Other studies in the Daphnidæ include an analysis of growth rates of genetically different strains of *Daphnia longispina*, which are found to differ

in growth markedly according to strain. Dr. Brown has been able to answer the question as to when the number of eggs to be laid is determined and also has shown that conditions which determine the number of eggs also simultaneously influence the sex of the offspring which develop from these eggs.

Mention is also to be made of the observations of G. A. Smith on the lag in the division time of *Paramecium caudatum*, which he finds is due to the physiological condition of the animal as well as changes in environment. This work has been reported in a preliminary communication.

It may be added that Dr. S. Hughes-Schrader has continued her work on a program of research on the sex conditions in certain Coccidæ (scale-insects), the investigations taking the course of breeding experiments and cytological analyses.

RED-CELL COUNT IN DIFFERENT STRAINS OF MICE

Since the literature on the field of erythrocyte count of the mouse blood showed a variation from 6 to 12 million corpuscles per cubic millimeter, it seemed advisable to check whether or not some of that variation was due to genetic causes. During the summer of 1934, therefore, Dr. R. J. Kamenoff made a preliminary study of the red counts of mice of a number of inbred strains maintained at this laboratory, *i.e.* Bagg albino, a dilute brown strain, a pink-eye dilute brown strain known as Storrs-Little, and a black strain known as C 58. All of these were in the 30th to 35th generation of brother-sister mating, so that each stock should be genetically pure. This preliminary study indicates that there is considerable range in each strain studied and that the different strains probably do not differ from each other in respect to their erythrocyte counts.

SPINDLE FIBERS

In the course of his investigations of the mitotic figure of dividing cells, Dr. Franz Schrader reached the conclusion that the fibrous structures of the spindle have an actual and physical basis in the living cell. Many observers have heretofore held these to be artifacts.

LEUKEMIA STUDIES

E. C. MacDowell, J. S. Potter and J. Victor

The group investigating mouse leukemia, consisting this year of Dr. E. C. MacDowell and Dr. J. S. Potter assisted by Misses M. J. Taylor and M. D. Findley, with Dr. J. Victor (College of Physicians and Surgeons) assisted by Mrs. O. Wintersteiner, working under a grant from the Carnegie Corporation, finds that the various phases of its work lead toward two main objectives: (1) The nature and origin of the changes in lymphocytes whereby they manifest the phenomena of malignancy; (2) the interaction of these cells and the hosts in which they are growing. These are distant objectives, for their attainment would amount to a solution of the analytical phase of the leukemia problem as well as providing an interpretative basis for malignancy in general. But the probability has become very strong that in attaining these goals new knowledge of general life processes of far-reaching significance will be required. For the cancer problem is approaching the

problem of living matter so closely that the solution of one may well lead to the solution of the other.

A question of very considerable importance for the understanding of life processes is the relation of genes and cytoplasm in development of individuals and in heredity. In terms of leukemic cells the problem asks if the different properties revealed by transmission studies of leukemic cells of different lineages owe their continuity to changes in genes or in some cytoplasmic mechanism. In other words, does malignancy arise from changes in genes in certain cells? The lines of leukemic cells, maintained by successive transfer from host to host are parallel to a group of species of natural protozoan parasites, but, as in the case of protozoa, genetic technique is not available to discover the rôle of genes, since genes can be detected only by means of crosses involving sexual reproduction. Thus a direct approach to this problem is impossible. But some progress is promised indirectly through the interrelation of leukemic cells and their hosts. In the last report the significant finding was announced that hosts, although naturally susceptible (in the sense that they are killed by the progressive growth of the transplanted leukemic cells), are, even so, not passive and, if the leukemic cells are introduced in small enough numbers, the hosts are able to destroy the cells and subsequently to destroy larger and larger doses of cells until they have become immunized to massive doses. In the current year the number of such immunized animals has been more than doubled (187 mice of strain C 58 immunized by line I cells, compared with 100 per cent susceptibility in several thousand controls). The technique of immunization has been progressively improved until each of the last set of 24 animals was successfully immunized. This phenomenon of immunization is not a peculiarity of the one combination of host strain and leukemic cell line, for it has been demonstrated to hold for other combinations of cells and hosts. But beyond indicating the generality of this phenomenon, these other combinations of lines and hosts lead to a consideration that is believed to have significant bearing. One might suppose that it would be easier to protect against less virulent lines of cells, but the reverse proved to be the case. Using less virulent lines of leukemic cells, the degree of success is considerably lower and the results less consistent. Further, a mouse, immunized to a highly virulent line of cells, may be killed (50 per cent of cases) by cells of a markedly less virulent line. How far the virulence as such is significant and how far virulence is an indication of specific cell-host differentials can not now be answered, although in the reverse of the experiment just mentioned, that is in mice immunized by the less virulent cells and subsequently tested by the more virulent cells, again only part of the mice survive.

IMMUNITY INDUCED BY EMBRYONIC TISSUE GRAFTS

Leukemic cells are a dangerous means of inducing immunity, for the exact control of minute doses is not possible and uncontrollable variations in extrinsic factors play some part, so that death instead of immunity can easily result. In September 1934 it was discovered that normal embryo tissue also will induce resistance and this without endangering the life of the animal. Instead of a long series of treatments extending over many

weeks, a single treatment may give a high degree of protection. It became immediately clear that immunity depends upon the differential relationship between the genetic constitution of the host and the immunizing tissue. With hosts of a given strain and leukemic cells of a given line, tissue of embryos of one genetic constitution immunize every mouse (93 tested). Tissue from embryos of another genetic constitution, administered in the same amount and in the same manner, failed to immunize a single mouse (75 tested), while embryos of a third genetic constitution immunized about half of the mice (65 tested). The importance of the genetic constitution of transplanted normal tissue in relation to the host has long been recognized. Dr. Leo Loeb and associates have made extensive microscopic studies on the interaction of host and graft of varying degrees of relationship. But while conclusions are given in terms of a systematic correlation between the host response to a graft and their pedigree relationship, no contribution was made to the question of the mechanism of hereditary transmission of the differentials involved. It might be expected that similar results would follow studies of the interaction of transplant and host when this is tested physiologically by the subsequent inoculation of malignant cells. But the experiments just reported constitute the first case in which such a result has been unquestionably obtained. Furthermore the clear-cut success or failure, according as embryo tissue of one or the other genetic constitution is used, offers a unique opportunity to test the rôle of genes in controlling such subtle characteristics, with its bearing on the unsolvable problem of the rôle of genes in differentiating lines of leukemic cells. Embryos of the first generation of a cross between the two strains giving the contrasting results are nearly as successful as those of the one strain (122 tested). That is, the power to immunize under the given circumstances dominates. In one of these two strains, a natural resistance to these leukemic cells and the ability of the embryo tissue to induce resistance are correlated; in the other, natural susceptibility and the inability of the embryos to immunize are associated, but these correlations are not causal, for the hybrid embryos do induce resistance and yet as hosts these same hybrids are susceptible to the leukemic cells of the same line.

Experiments with embryos of the back-cross generation are incomplete, but it is clear that different embryos in this generation give different results.

NATURE OF IMMUNIZING PROCESS

The nature of the immunizing process has been studied by Dr. Potter. Leukemic cells *in vitro* gave us under the microscope no evidence of harm from serum of immunized mice. The fate of leukemic cells inoculated into mice previously immunized has been followed in animals taken at regular intervals. Microscopic examination of these tissues shows that at first the inoculated cells continue to proliferate and may form lesions in the same places as in unimmunized hosts, but these lesions never become large and the rate of cell division is several times less than in unimmunized mice of the same strain. Within the first four days degeneration of the leukemic cells usually takes place; this process is initiated in cells at the margins of lesions and spreads inward. Host phagocytes then appear and clear up

the débris. At this stage lymphoid cells of the host may appear for the first time. By the 6th or 7th day, no evidence of the inoculation can be found. Thus it appears that immunity to transplanted leukemia is not the result of blockade or invasion of lesions by normal host lymphocytes, as has been strongly argued for the case of induced resistance to other types of neoplasia.

Another approach to the nature of this immunity has been made by Dr. Victor, who finds that the metabolism of leukemic cells in serum of immunized mice is identical with that in serum of unimmunized mice.

Although the microscopic studies seem to require the assumption of a humeral material, it has become clear that this material does not reside in the serum in the absence of living leukemic cells; immunization is the facilitation of the production of some material upon suitable stimulation by malignant cells.

While metabolism of leukemic cells in serum of immunized and unimmunized mice was the same, leukemic cells in serum of the hosts in which they were growing were found to give a markedly different result. Dr. Victor learned that this was due to the difference in blood-sugar content of the serum. Here again there was no difference between normal and immunized mice, both of which gave a rather high blood-sugar content (200 mg./100cc.), but in unimmunized mice in which leukemic infiltration was approaching the final stage, the blood sugar was extremely low (20 to 50 mg./100cc.). Another significant finding concerns the use of glucose, namely, that leukemic cells do not act upon glucose by oxidation, as do normal cells, but by fermentation alone. This was demonstrated for three lines of transplantable leukemia, by the effect of glucose upon the respiratory quotient. Since fermentation uses sugar very much more rapidly than oxidation, there may be a connection with the low blood sugar actually found.

The supposition that death might be directly due to blood-sugar deficiency was flatly denied by the failure of glucose treatment to influence the fatal course of the disease. With blood sugar in some way involved, attention is immediately drawn to a possible endocrine connection and especially to the adrenal gland. At this point again the physiological and microscopic studies lead in the same direction, for Dr. Potter finds that the only morphological indication that a mouse has been immunized is hypertrophy of the thymus. While in a susceptible mouse, given a small enough dose for it to possibly survive, there occurs a rapid involution of the thymus; if the mouse does survive, the thymus regenerates and becomes hyperplastic. The thymus is involved in immunity; blood sugar is reduced in death from leukemia; regulation of blood sugar is a function of the adrenal. The intimate interrelation between the thymus and adrenal gives suggestive significance to the juxtaposition of these various observations.

SPONTANEOUS LEUKEMIA

Although much of the work has been done with experimental leukemia, every advance leads directly or indirectly toward an understanding of the spontaneous occurrence of leukemia, which is so closely parallel to the

human forms of the disease. One of the first questions raised by the successful immunization by means of leukemic cells was the influence of such immunity upon the incidence of spontaneous leukemia, which occurs naturally in the strain under consideration in about 90 per cent of the mice. In order to learn this, it was first necessary to determine whether this immunization would persist. All mice tested one, two and three months after first resisting the standard dose of leukemic cells were found to be still immune; a few mice were tested after an interval of 6 months and these also were still resistant. However, to insure maintenance of immunity at full strength, successive leukemic inoculations were given at monthly intervals after the test periods mentioned, until the animal finally died. In some cases this has meant 15 monthly inoculations with the massive standard dose. Most of the mice in a large group are now dead; these have given as high an incidence of spontaneous leukemia as the entirely untreated mice of the same strain. Resistance to highly virulent cells does not insure resistance to the low virulence of the cells of a spontaneous case. This is the second time such a situation has been encountered.

There can be no doubt but that different properties are required to kill the leukemic cells that occur spontaneously and the highly malignant inoculated cells. Even after a spontaneous case was frankly manifest, a dose of the highly virulent cells would be resisted and the cells destroyed, while the cells of the spontaneous case continued their fatal progress. This was due to the immunization and not to some pre-occupation by the spontaneous cells, since unimmunized mice with spontaneous leukemia die regularly in four days when inoculated with the same dose of the same cells. In some cases death from spontaneous leukemia occurred two or three weeks after an inoculation, and the microscopic sections gave no evidence of the previous inoculation; but in other cases animals very sick with spontaneous leukemia died soon after an inoculation, with death perhaps hastened by the handling or shock of inoculation. In such cases the inoculated cells could often be found, even forming small lesions, but showing unquestionable evidence of destruction and regression, while the lesions of spontaneous cells were progressing freely.

If a very small number of leukemic cells leads to the development of resistance, why does not the small number of cells at the beginning of a spontaneous case block their own further development? Is it that they are not sufficiently virulent to start the reaction in the animal? And is virulence merely a measure of the differential between a cell and its host? And is that differential changed in the course of the spontaneous disease as in the course of transplantation, thereby giving rise to the phenomenon of increasing virulence?

ENDOCRINE STUDIES

*O. Riddle, R. W. Bates, C. S. Moran, G. C. Smith, E. L. Lahr and
J. P. Schooley*

The hormones of the anterior pituitary gland are now recognized as agents which contribute much, and each of them in very specific ways, to the development of the bodies of all vertebrate animals. It is becoming

clear that these particular internal secretions become active in very early life and that both developmental defects and overgrowths may attend their early dysfunction. Finally, during adult life these hormones play a part—still relatively little investigated—in human health and disease.

During the last year most of the effort of Dr. Riddle and his associates has centered upon the products of this gland, and upon specific things which some of these hormones accomplish in the body. These studies have been greatly aided by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

EFFECTS OF PROLACTIN AND FOLLICLE-STIMULATING HORMONE ON OVARIAN TUMORS IN FOWL

It was reported last year that our observations on the ability of follicle-stimulating pituitary hormone to increase, and of prolactin to decrease, the size and activity of adult germ glands of birds had led to a study of effects of these two hormones on ovarian tumors of fowl. This particular study has been terminated because of the scarcity of suitable tumors, and by our inability to make successful implants of any of the few tumors found in nearly 300 hens examined. Three malignant tumors were found and subjected to observation and treatment—two of them for 8 and 14 months. The pathology of these cases, studied at various stages by Dr. C. S. Moran, suggests some effect of treatment, except in a short-lived case of adenocarcinoma of the ovary in which the animal died during biopsy one day after a series of 12 daily injections of prolactin. A case of carcinoma—of ovarian or of adrenal origin—was twice treated (10 and 30 days) with prolactin, and in a terminal period was well stimulated with follicle-stimulating hormone from her own pituitary (as proved by egg production); from this case evidence for depression of the tumor growth by prolactin was obtained. The third case, a metastasizing adenocarcinoma of the ovary, was probably stimulated in its growth by injection for 10 days with follicle-stimulating hormone. These few experimental tests are quite inadequate. They appear, however, to offer some support for the theory—first derived from the study of the action of the two hormones on normal gonadal tissue—that follicle-stimulating hormone may act as an inciting or causative agent for certain tumors arising primarily in the germ gland, and that prolactin may act specifically against the growth of these particular tumors.

MATERNAL BEHAVIOR IN RATS INDUCED BY PROLACTIN

Results reported last year by Riddle, Bates and Lahr showed that in laying hens the incubation instinct, or broodiness, can be initiated by injections of prolactin. That study was continued on rats on the theory that the maternal instinct of mammals is evolved from the incubation instinct of lower forms and should therefore also be under the control of prolactin. This has proved to be the case; virgin rats whose ovaries have become fairly mature may, even after removal of their ovaries, quickly acquire the maternal instinct as a result of a few or several daily injections of prolactin. Previous to this study, Wiesner and Sheard had observed that virgin rats injected for some 28 days with crude pituitary extract usually began to show maternal behavior a few days after such injections were discontinued.

The investigation of this subject is complicated by the circumstance that some virgin rats, which we call "reactors," will spontaneously have and exhibit the maternal instinct without any injection whatsoever. This presumably means that their own pituitaries have supplied them with extra amounts of prolactin, or that in such individuals the reactions involved in this instinct have low thresholds of response to prolactin. In any case these "reactors" (21 per cent of 160 tests) must be found and eliminated from the group of rats selected for special study. The criterion for presence of maternal instinct is that the rat shall persistently respond to the presence of a young rat (dropped into the front of her cage) by taking it in her mouth, carrying it to her nest and there covering or caring for it. Most proved non-reactor virgin rats (49 of 62) begin to give this maternal care during a series of 3 to 15 daily injections of 10 to 50 units of prolactin; a few (3 of 62) carry young to nest but give no further care; curiously, some (3 of 62) give the reaction only after stopping the injections, and a few (7 of 62) fail to show the maternal response at all within a period of 30 or 40 days. Four virgins that did not develop the instinct under prolactin, later developed it during (2 cases) or after (2 cases) a series of injections of whole pituitary extract rich in prolactin; three such virgins from the same litter, and having otherwise a peculiar history, completely failed to show the instinct during or after injection with a series of pituitary hormones. Prolactin apparently developed the instinct in 2 of 8 normal male rats and in 5 of 6 castrate virgins.

The injection of other pituitary hormones than prolactin, or of hormone mixtures containing little or no prolactin, is so rarely followed by a positive response as to indicate that none of them induces maternal behavior. It was further observed that after the induction of maternal behavior with prolactin, three to five injections of follicle-stimulating hormone will quickly erase this behavior in normal virgins (5 of 6 cases), though such injections fail to do so (3 cases) in castrates of both sexes.

This demonstration of the dependence of an instinct upon a hormone contributes to our understanding of development and of animal behavior and psychology. To theory of development it adds the important information that a hormone has been found to act upon a variety of tissues and processes (lactation, crop-gland, germinal tissue, and cooperation with nerve tissue in developing an instinct), and at the same time it maintains an underlying unity of the several responses it evokes. In this case, despite the varying kinds of tissue involved, all of the responses are concerned with the feeding and care of young. Again, the present instance once more indicates the periodic release (at least in adult life) of this hormone, and the basis of a particular type of cyclic behavior is thus made comprehensible.

Though the mechanism by which the hormone affects the neural state or function is wholly unexplored, this case provides a superior instance of somatic or extra-neural participation in a normal psychic state. The administration of this hormone to an otherwise adequately developed rat obviously endows the animal with a quite new normal and necessary psychological experience; and, the apparently legitimate and necessary inference from the induced behavior is that we have thus temporarily added to such a rat a new element of consciousness.

HORMONES OF THE ANTERIOR PITUITARY

During the year Dr. Bates and Dr. Riddle have submitted for publication a revision of the method of extraction and purification of prolactin. The tissue is first extracted with 60 to 70 per cent alcohol at pH 9.0 to 10.0, and this is followed by complete precipitation of the active principles at a higher alcohol concentration and at pH 6.0. The prolactin is next separated from the bulk of follicle-stimulating and thyreotropic hormones by taking advantage of the insolubility of prolactin between pH 3.0 to 4.0 in the presence of sulphates. The hormone is further purified through use of its solubility in aqueous alcohol. About 70 per cent of the prolactin present in the original tissue is thus obtained in one fraction uncontaminated by follicle-stimulating and thyreotropic hormones. At pH 8.0 prolactin can be heated to boiling for one hour or to 60° C. for 5 hours without great loss of potency.

Last year measurements (assays) were reported for amounts of prolactin contained in the anterior pituitary glands of cattle embryos, of veal calves, of steers, adult bulls, non-pregnant cows, cows in early and in late pregnancy. The approximate amount of follicle-stimulating and of thyreotropic hormone contained in those several types of cattle pituitaries can now be stated. In this study by Dr. Bates, Dr. Riddle and Mr. Lahr, smallest quantities of thyreotropic hormone were found in the glands of embryos and adult steers. Greatest amounts of follicle-stimulating hormone were found in glands of cows in early pregnancy, and least in adult steers (castrates). Other previous assays of the latter hormone have used the growth response in rodent ovaries, and there the amount of growth seems also to be greatly affected ("augmentation phenomenon") by something other than the follicle-stimulating hormone. Since our assays were made on the basis of the growth response of the immature dove testis—which is unaffected by any other pituitary substance—we seem to have corrected a mistaken and wide-spread impression that an accumulation of the follicle-stimulating hormone occurs in the pituitaries of castrates.

Connected with the use of the immature dove testis for assay of the follicle-stimulating hormone is the fact, ascertained by Dr. Bates in the inspection of past records, that the males of our dove races and hybrids show marked differences in the "unstimulated" or normal size of their testes. Birds of about 2.5 months of Race 72 show an average testis weight of only about 4.5 milligrams; at the other extreme these glands of Race W weigh about 14 milligrams. The real meaning of these differences is not clear, but it is evident that in our earlier task of "standardizing" our races we provided a hereditary basis for a graduated scale of difference in testis size.

The minute size of the testes of practically full-grown doves and pigeons at the age of two months, with subsequent amazingly rapid growth of those glands, earlier led Dr. Riddle to suggest that the pituitaries of these birds release no trace of follicle-stimulating hormone during this early juvenile period. Also, that the extraordinary sensitivity of the immature bird testis to follicle-stimulating hormone rests upon their never having been exposed to traces of that hormone. Dr. Riddle and Dr. Schooley have made and reported a rigorous test of the more inclusive question, namely whether the immature pigeon pituitary contains (not merely whether it releases) a dis-

coverable trace of follicle-stimulating hormone. The method used was to implant pigeon pituitaries—from young common pigeons in some tests, from old pigeons in others—into the smaller and highly sensitive immature male ring dove. It was found that fewer than five pituitaries of adult pigeons caused notable testis growth in the recipient dove; but even 30 pituitaries from nearly full-grown but suitably immature pigeons failed to stimulate growth in the testes of the recipient dove. Since the immature pigeon testis is much used in pituitary hormone assay it is well to know the reason for its unusual sensitivity; and when this test is used for the assay of mixed extracts, it is of much consequence to know that nothing in the mixture can cause a change in output of follicle-stimulating hormone from the bird's own pituitary. We now know there can be no such change since the immature bird's pituitary can not yet produce the hormone.

Directly or indirectly one or another anterior pituitary hormone affects the carbohydrate metabolism, and it has been alleged that another pituitary hormone regulates the blood calcium through the parathyroid glands. To obtain information on these points, Dr. Riddle and Dr. Louis Dotti are investigating the blood sugar and calcium in normal and hypophysectomized animals injected with available pituitary hormones. The only part of the study now wholly concluded is that which concerns the suitability of the pigeon for such studies on the blood calcium. Here it was found that 10 to 20 units of parathormone (the parathyroid's own hormone) caused a marked and rapid rise (4 to 8 hours) of the serum calcium. The average increase obtained was 18 per cent in normal, 24 per cent in hypophysectomized, and 30 per cent in thyriodectomized birds. It is thus shown that pigeons are suitable animals for a study of the relation of the pituitary to parathyroid activity.

The effects of complete removal of the pituitary on the adrenals, thyroids and gonads of pigeons have been studied by Dr. Moran. It is found that these organs suffer rapid and severe damage, but details concerning the nature and extent of injury to each organ in both complete and incomplete hypophysectomy should await the conclusion of the study.

The life cycle and the reproductive cycle of pigeons present investigators with unusually distinct expressions of pituitary quiescence and activity and this fact is being extensively utilized by Dr. Schooley and Dr. Riddle to obtain a better interpretation of the histology of the anterior pituitary gland. It is thought that satisfactory knowledge of the types of secretory cellular activity should either deny, or confirm, our attempts by other methods to learn the actual or probable number of pituitary hormones. One apparently definite result has attended our earliest efforts. It is earlier noted in this report that the pituitary of the juvenile (2 months) pigeon contains no follicle-stimulating hormone. The histological study has shown that the pituitaries of such immature pigeons contain few basophile cells and that these lack the characteristic granules of the active basophile cell. Also, that in these same glands the eosinophile cells are unusually numerous and active—this activity being associated, at least temporally, with body-growth. In consonance with the result first stated it is found in occasional birds which have attained adult age without development of the germ glands, that the

basophile cells are comparable with those of very young pigeons. The incomplete study has also indicated that eosinophile secretion occurs as the crop-gland (prolactin effect) develops, and that storage of eosinophile secretion occurs when prolactin is supplied to the bird by injection.

ACTION OF ANTERIOR PITUITARY HORMONES ON METABOLISM AT VARIOUS TEMPERATURES

A comprehensive study, lasting two years, has been made of the action of various hormones of the anterior pituitary on heat production in doves and pigeons. The investigation had two distinct parts and was carried out by Dr. Riddle, Mrs. Smith, Dr. Bates, Dr. Moran and Mr. Lahr. The first task was to separate and assay in our laboratory some of the pituitary hormones, and to obtain similar or other preparations from other laboratories of America and Europe. These latter preparations, like our own, were subjected to our own tests and assays for prolactin, follicle-stimulating and thyreotropic hormones. From this study we were able to select for use in metabolism work some preparations which contained, of these three hormones, only prolactin, only follicle-stimulating and others having thyreotropic plus only follicle-stimulating hormone. Other crude extracts were so made as to contain probably all existing anterior lobe hormones.

In the second part of the study each of these types of hormone was injected during 9 days into groups of doves or pigeons (or of both), and the effect of the hormone (or preparation) on the heat production of each injected bird was measured after 3 and 9 days of such injections. In fact, such groups of injected birds were measured at three temperatures—30°, 20° and 15° C.—and each hormone was tested on normal doves, on normal pigeons, on hypophysectomized and on thyroidectomized pigeons.

These studies contribute much to our knowledge of the physiology of the anterior pituitary. The follicle-stimulating hormone was shown to have no effect on the metabolism of any type of bird at any temperature. It was learned that, in addition to the thyreotropic hormone already known to have such action, prolactin increases the rate of heat production when measurements are made at or near the critical temperature (30° C.); also that this hormone, unlike the thyreotropic, does not act through the thyroid but in a way now unknown. It was shown further that all available preparations of the "growth hormone" notably increased the basal metabolism (at 30° C.), and that all contained some prolactin and some thyreotropic hormone. Again, it was found that small amounts of thyreotropic and prolactin have definitely greater effect on the metabolism when they are combined than when given separately. These results therefore support the view, first developed in this laboratory, that there is no separate and distinct growth hormone in the pituitary gland; the unquestionable growth response, hitherto considered evidence or proof for the existence of a particular (growth) hormone, is apparently a response to the joint action of two or more hormones, notably thyreotropic and prolactin.

An astonishing and inexplicable effect of low temperature was found in this study. The same hormones, prolactin and thyreotropic, which increase the basal metabolism at 30° C. actively *decrease* the metabolism of both normal and hypophysectomized animals kept and measured at a low tempera-

ture (15° C.). In other words, precisely when more heat is most needed, least heat is obtainable from the periodically injected hormone. Since we here find that the organism's normal physiological agents for heat production yield contrary effects according to temperature, one may note the challenge this brings to Rubner's theories of heat production. For the present the matter must be left as a paradox.

EFFECTS OF LIGHT ON REPRODUCTION

Certain phenomena of reproduction in ring doves, such as the hour at which an egg leaves the ovary and the hour at which the fully formed egg is laid, show a peculiar clock-like regularity with relatively small fluctuations. This year the source of these fluctuations has been determined by 1254 observations made by Dr. Schooley on the birds of our colony. It is found that on cloudy days the first egg of a pair (usually laid about 5:00 p.m.) is laid approximately 30 minutes *earlier* than on bright days; and that the second egg of a pair (usually laid about 9:00 a.m.) is laid approximately 30 minutes *later* on cloudy days than in fair weather. It has also been determined that ultra-violet rays (their presence or absence over weekly or monthly periods) influence the ability of the bird's oviduct to expel an egg when fully formed. Birds chronically unable to expel some or most of their eggs have this disability corrected by 20- to 30-minute daily treatments with ultra-violet rays. It is known that light, or change of light, is related to some periodic changes in the pituitary gland and the nature of this relationship is under careful study.

In a somewhat related study, Dr. Riddle and Dr. Schooley find that the injection into doves of the hormone of the mammalian corpus luteum (progestin) produces certain peculiar effects. Parts of the study are unfinished, but three things have been made clear. The normal mechanism of dehiscence (ovulation) of ova from the ovary is disturbed; the formation of normal egg-shell in the oviduct is adversely affected; and when injections of progestin (but not of estrin) are initiated at or near the beginning of an incubation cycle, the broody instinct is lost or much disturbed. On the one hand these results lead us to suspect a type of histological change in the pituitary which is now under study; on the other hand they provide reason for doubting the normal existence of the corpus luteum hormone in birds.

BASAL METABOLISM OF DOVES AND PIGEONS

The study of the metabolic differences associated with race, sex, age and hybridity has been continued in collaboration with Dr. F. G. Benedict, director of the Nutrition Laboratory, and with the assistance of Mrs. Guinevere C. Smith. The importance of adequate knowledge of basal heat production in our many races and hybrid types has been emphasized during the past 18 months by other studies which show that these types differ markedly in their response to prolactin and in the size of their germ glands during pre-adult life. The work of the past year has much emphasized the need for repeating all measurements at various (high and low) temperatures. A study of the calorigenic action of alpha-dinitrophenol at 15° and at 30° C. gave the interesting result that this powerful drug, somewhat like two pituitary hormones described elsewhere, stimulates heat production less at 15° than at

30°; also that in a thyroidectomized pigeon the drug has relatively little effect at either temperature. Other workers have recently found in intact animals a similar influence of low temperature on the calorogenic action of this drug and it now seems that some or much revision of current theories of heat production is required to accommodate the new facts.

Completion of a study of effects upon heat production of removal of the hypophysis has shown that when measured at 30° C. this operation, performed by Dr. C. S. Moran, results in lowering the heat production by about 33 per cent; in measurements made at 20° a decrease of only 20 per cent was found.

ANTHROPOLOGY AND HUMAN GENETICS

M. Steggerda

ANTHROPOLOGY OF MAYA INDIANS

It has been found by Dr. M. Steggerda that the Maya Indians in the Eastern part of Yucatan (Chichimila) were statistically equal in stature to those in the Chichen Itza area. Their statures equal 156.62 ± 0.68 cm. for men and 142.85 ± 0.46 cm. for women, as compared with the Chichen males which are 155.11 ± 0.40 cm. and females which are 142.72 ± 0.42 cm. These differences are not significant statistically. It is of interest also to find that the Mammes and Quiché males measured by us in Guatemala averaged 154.66 ± 0.47 . These averages for stature are statistically equal to those obtained by Williams and Starr on previous expeditions to these parts of the Yucatan peninsula.

GROWTH IN CHILDREN OF DIFFERENT RACES

The work of Dr. Steggerda on the comparative growth of children of different races has progressed to the stage where we have standards made for each of 32 dimensions for both Navajo and White individuals. These standards were made from 50 individuals of each age and sex for both races. It was found that the average statures for these 50 individuals by years did not differ statistically from averages based upon larger numbers, *e.g.* about 100 to 150 for each age and sex. This proves that our sample of 50 is an adequate and representative group upon which to base predictions. Figures proving this statement are given below.

The significance of the difference between the mean for height for the large sample and the mean for height for the small sample.

Years		6	7	8	9	10	11	12	13	14	15	16	17	18
Diff./P. E. Diff.	♀	0.4	0.8	0.3	0.9	0.2	0.7	1.0	0.7	1.3	0.5	0.5	0.1	0.4
Diff./P. E. Diff.	♂	.4	.9	1.9	.4	1.0	.7	.6	.2	.1	3.0	.3	.2	.2

A height and weight chart has been made for the Navajo children. This is the first height and weight chart made for races other than Whites and it shows definitely that the Indians' weights are considerably less for a given height than the usual weight predictions for Whites. Height, however, is not as good an indicator of weight as are other body measurements, for example the correlation between chest girth and weight is better than height *vs.* weight. When such measurements are tabulated it is seen that the correlation between chest girth and weight remains high between the years 14

and 18, whereas between height and weight for these years there is practically no significant correlation.

It is of interest also to find that in the three races studied (Whites, Negroes and Navajos), the age at which the curve for stature for girls crosses the male curve is practically the same for these three races—namely, at $10\frac{1}{2}$ and $13\frac{1}{2}$ years.

Concerning the growth of the Maya children, nothing has been concluded. However, we have 136 children in our growing series who have been measured over a period of five years.

DERMATOGLYPHICS IN MAYA INDIANS

A paper on "Palmar Dermatoglyphics," with special reference to the Maya has been completed by Dr. and Mrs. Steggerda. The palm prints of the Maya are interesting since they possess many of the characteristics which are present in the Mongolians, *e.g.* (1) a high frequency of the 9.7.5.—type of formula; (2) an unusually vertical general configuration of the palm, as indicated by the proximal terminations of line A; (3) the frequent reduction of line C to a rudimentary and more often a totally absent condition; (4) the occurrence of a single comparatively low axial triradius; (5) an unusually low incidence of the hypothenar pattern, with apparent reversal in the percentages found in left and right hands as compared with left-right differences in the whites; (6) the low incidence of the second- and third-interdigital patterns; and (7) the exceedingly high frequency of the thenar-first interdigital patterns.

It is most significant that the Chinese studied by Wilder (1922) conform in every detail except the last to these characteristics found in the palms of American Indians. It is only in the low percentage of the thenar-first interdigital pattern that the Chinese and Mongolians, in general, differ significantly from the American Indians.

VITAL STATISTICS OF PISTÉ, YUCATAN

Concerning the vital statistics and family studies collected by Dr. Steggerda in Pisté, Yucatan, a summary has been made by him as follows:

(a) In 1935 there are 415 inhabitants in the town: 207 males and 208 females.

(b) 17.8 per cent of the people are under 5 years of age; 25.5 per cent are between 5 and 14 years; 21.4 per cent are between 15 and 24 years; 25.3 per cent are between 25 and 44 years; 7.0 per cent are between 45 and 70 years.

(c) The average birth rate for 17 years is 60.1 (per 1,000).

(d) The death rate for the 17 years is 31.7 (per 1,000).

(e) Of all the children born, in 109 families studied, 17.2 per cent died in infancy. (56 per cent were males and 44 per cent were females.)

(f) The secondary sex ratio of these children is 108.5 males to 100 females.

(g) The average interval between births (for 147 births from 51 mothers) is 28 months.

(h) From 33 completed families, the average number of children per family is 6.69.

(i) The average age of women at marriage is approximately 15.7 years.

- (j) The average age of mothers at the birth of the first child is 18.0 years.
- (k) Only one woman out of 107 marriageable females was unmarried, and this woman was blind.

MAIZE PRODUCTION IN YUCATAN

Cooperating with the Division of Historical Research, Dr. Steggerda has conducted a series of experiments involving soil-analysis, with the view to determining the relation between maize-yield, soil-deterioration and the abundance of weeds.

STUDIES IN TASTE SENSITIVITY

In earlier reports, it has been shown by Dr. A. F. Blakeslee that taste sensitivity for P.T.C. (phenyl-thio-carbamide) is inherited. During the past summer, with the assistance of Mrs. T. N. Salmon, his study of taste has been extended. Thresholds of 47 subjects were obtained for 17 different substances including P.T.C. A factor of two was used in making dilutions. Great differences were found between the substances in respect to the range of threshold shown by subjects. P.T.C. had the greatest range with 13 grades, which means that the least acute tasters required a solution over 4000 times as strong as the most acute tasters in order to detect a solution of P.T.C. Although there is a tendency for those who are acute tasters for P.T.C., for example, to be also acute tasters for other substances and vice versa, there are many individual exceptions. Fifteen out of the 47 subjects were in the least acute grade for one substance and in the most acute grade for another substance. A special study of the reactions to P.T.C. showed that some subjects vary considerably in their threshold reactions from time to time.

At the International Flower Show in March in New York City it was possible to have an exhibit which tested differences between people in the sense of smell. Over 8400 people recorded their reactions to a pair of flowers as to whether any odor could be detected and if so whether it was weak, medium, or strong, and pleasant, indifferent or unpleasant. People were found to differ as widely in respect to their acuteness in the sense of smell as has been found for the sense of taste. The study of thresholds of smell is much more difficult than that of taste. The exhibit was in the nature of a survey which oriented us to some of the difficulties involved and at the same time gave information regarding the range of variability in respect to the odors tested.

STUDIES IN EUGENICS AND HEREDITY

H. H. Laughlin

HEREDITY IN THE THOROUGHBRED HORSE

Since the last annual report, substantial progress has been made toward the more exact determination of the rules by which nature governs the transmission of racing capacity from one generation of the Thoroughbred horse to the next. Both the development of the theory and the practical use of the General Formula of Heredity were advanced. This recent development may well be summarized under the heading "The Resultant Probability."

(a) *The Resultant Probability* $K=f(M_{1, 2, 3, \dots, n}, R)$

This principle concerns the prediction of racing capacity which will be developed in a particular random-selected or pre-indicated foal, based upon the racing capacity of each of its nearest blood-kin. Given a definite kinship, such as the sire-foal kinship, with the definitely computed racing capacity of each sire and foal involved, cross-section all other factors so as to provide their random representation in the sample; we can then readily plot the definite probability-curve for the distribution of racing capacity in the offspring of sires of a given racing capacity. Such distribution is herein called a piece of independent probability-evidence. The prediction may not be very good, that is, the curve may be low and flat, but it is definite if all other factors are completely and randomly cross-sampled.

The definition of independence becomes of very substantial importance, and in genetics the several distinct kinships prove to be amply distinct to constitute the subjects of pieces of such independent evidence. Thus the racing capacities involved in the sire-foal relationship constitute one piece of independent probability-evidence; the dam-offspring relationship another; the sire's sire another; the sire's dam another; and the dam's sire and the dam's dam still others. Each piece of such probability-prediction-evidence constitutes a definite component in the resultant prediction-formula.

Heretofore, whenever a number of pieces of independent probability-evidence were given, no accurate or adequate method had yet been developed which would compute the resultant probability-distribution of all of these several pieces of independent probability-evidence when acting simultaneously.

The thing reported now is the discovery of the correct way to compute the probability-resultant of a group of several pieces of independent probability prediction-evidence. Each of these several constituent factors when taken independently must be related as a definite causal factor of the same thing-predicted. In the present case we are dealing with racing capacity in the running horse. The particular M's are independent causal factors; in each case M is racing capacity in a definite near blood-kin of the particular foal. R is the thing-predicted, that is, racing capacity in the subject foal.

The general or pattern formula for such probability-prediction is

$$K_P = K_{fcP} \epsilon^{\frac{-(FC_{\Sigma} \sim R)^2}{2 \left(\frac{0.3989 \cdot q}{K_{fcP}} \cdot \Sigma AP_{\sigma t} \cdot 2 \right)}}$$

Explanation of this formula and its necessary intermediate computations follows:

K_P is the probability that the pre-indicated individual will fall within the selected class-range of $R \pm \frac{q}{2}$ units on the common R-scale.

q thus equals the width in R-units of each class-range of the thing-predicted. This width or class-range must be constant for all prediction-bases and for the probability-resultant.

THE PROBABILITY-RESULTANT OF SEVERAL INDEPENDENTLY OBSERVED PROBABILITY-EVIDENCES

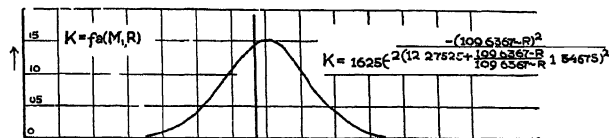
An example of the General Pattern Formula applied to a case which consists of four pieces of mutually independent probability-evidence—that is, as a case with four different M's or Prediction-bases—in reference to the same R or Thing-predicted, all other speed-influencing factors being randomly represented.

Shrinkage / yes. K-un-
changed throughout.
R-zero is charged to R-locus
of Highest Common Prob-
ability (H.P.) = 107.2
in final computations.

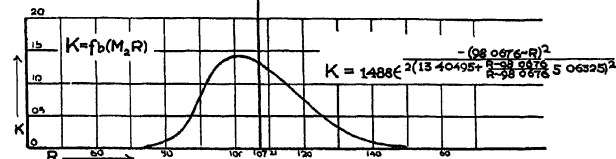
(3) Repeated-Sample Area
(if the four pieces of
evidence are not mutu-
ally independent, but
are simply repeated
samplings from the
same M throughout) =
1,000 = K-summation
of all such strips under
the "dotted curve."

(2) Resultant Area (if the
four pieces of evidence
are mutually independ-
ent) = 1,000 = K-
summation of all such
strips under the
"Shaded Area" bound-
ary curve.

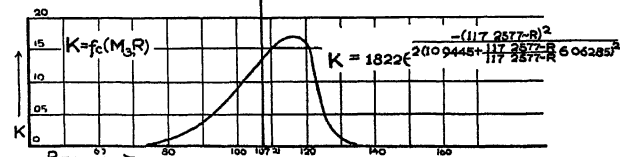
(1) Summation Area
= 1,000 = n
= K-summation of all
vertical strips (q =
R-units width. Herein
q = b) under the 2-
area curve.



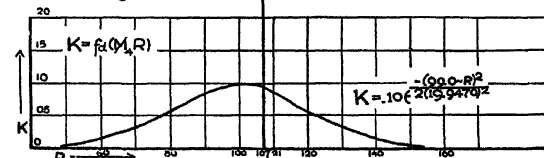
1 Racing Capacity of the Dam's Sire = 117.5 = M_1



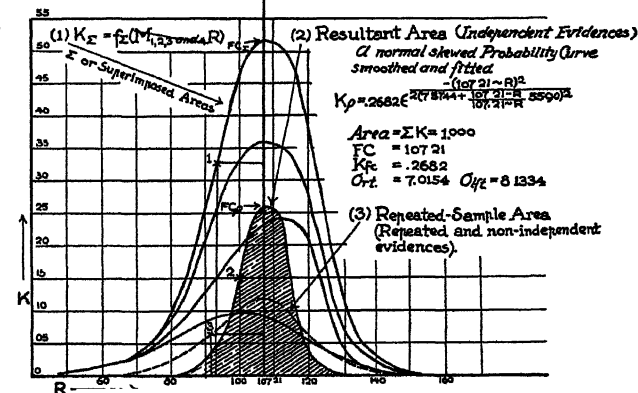
2 Racing Capacity of the Sire = 97.5 = M_2



3 Racing Capacity of the Dam = 127.5 = M_3



4 Any other independent $K = f(M, R)$ Quality whatsoever = M_4



PROBABILITY RESULTANT (Shaded Area).

INTERMEDIATE COMPUTATIONS:

The Highest Common Probability = $FC_{\Sigma \text{ and } P}$

(1) $FC_{\Sigma \text{ and } P}$ is the fluctuation-center on the common R-scale of ΣK , that is, the summation of all constituent probability-values; and it is also the R-locus of K_{fcP} or the *Highest Common Probability* of any $R \pm \frac{1}{2}$ class-range of the thing-predicted by the resultant probability distribution.

In the accompanying example (see diagram p. 59) the several independent probability-distributions are plotted on the same R-scale, and each with the same but independently based K-scale. Both approximately by the graphical method, and accurately by the calculus, there is found the R-point, directly above which the slope of the summation probability curve equals zero. In the example this R-point = 107.21. This means that with all constituent evidence duly weighted, the Highest Common Probability, which is also the fluctuation-center of offspring values, lies at the center of the class-range $R = 107.21 \pm 2.5$.

(2) K_{fcP} = the actual K or probability-value of this resultant-Highest Common Probability. It is equal to the ΣK 's at FC_{Σ} divided by the square root of n . n = number of independent probability evidences in the resultant. In this case $K_{fcP} = 0.5364 \div \sqrt{4} = 0.2682$.

(3) $\Sigma AP_{r \text{ or } 1}$ = the summation, in the final resultant probability-distribution, of all of those probabilities (or areas) supplied by all constituent pieces of probability-prediction-evidence (Manerkonic cross-sections actually used), which, on the same R-scale, are related consistently to $R <_{fc\Sigma \text{ and } P}$ or consistently to $R >_{fc\Sigma \text{ and } P}$ (i.e. graphically the summation of constituent areas consistently to the right or to the left of $FC_{\Sigma \text{ or } P}$).

Subscripts as herein used: The numerals 1, 2, 3, . . . n refer always to the constituent pieces of probability evidence, i. e. the Manerkonic cross-sections 1, 2, 3, or n ; the subscript Σ refers always to that probability-distribution which is either the mathematical or the graphical summation of the several constituent pieces of probability-distribution-evidence; the subscript P refers always to the probability-resultant of the several prediction-bases actually used, rather than to any one of them; and the subscript s refers to symmetry or bi-symmetry.

Independent evidences must be considered. When seeking the resultant-probability-distribution, it is useful to contrast the different mathematical treatments required by a group of independent probability-evidences on the one hand, and on the other by two or more probability-distributions selected from the same population; that is, by two samples of the same stuff and population, contrasted with two samples each an independent sample from an independent stuff. If the pieces of evidence are independent, then the formula for the probability-resultant, as graphically shown in the accompanying diagram, works out. If, however, the evidence is overlapping or duplicated (that is, based on one definite M kind and value, one probability-distribution of R or the thing-predicted is computed and plotted, and then another sample from the same stuff or population is taken in the same manner), the resultant-formula for a group of independent probability-evidences will not apply. Two such dependent or repeated samples are

simply added together, that is, the one probability-distribution curve is supermounted above the other, and the K-value for each R-class divided by two—the number of times the sample is duplicated.

In summary, when the probability-evidences are independent, in providing the correct probability-resultant, which is the main thing sought, the new formula exercises the following properties:

(a) Regardless of its value, every piece of constituent evidence, which is in hand in reference to any near-kin, is used and correctly stressed in the resultant.

(b) The probability-resultant piles up evidence of probable offspring or R-values, so that mathematically—as in common sense—offspring-values with a high K or probability of occurrence, as rated independently by each of several independent M's, that is, by the several constituent pieces of independent probability-evidence, tend to become still more probable, while low probabilities so rated tend to become still less probable, in the resultant; it is not simply an equable piling-up or averaging of all probabilities.

(c) This new general or pattern formula for the probability-resultant can be applied in genetics to any trait or quality which is measurable in the individual and which to any degree is shown to run-in-the-family.

A DECADE OF PROGRESS IN EUGENICS

During the year the scientific papers of the Third International Congress and Exhibit of Eugenics, which were held in New York in 1932, were edited and published. This report appeared in one volume entitled "A Decade of Progress in Eugenics," which topic connotes the development of eugenics as a science during the period between the Second International Congress of Eugenics held in New York in 1921 and the Third International Congress and Exhibit of this series which were held, again in New York, in 1932. This volume was dedicated to Mrs. E. H. Harriman, the founder of the Eugenics Record Office, and was sponsored by the Carnegie Institution of Washington through the Eugenics Record Office.

Among the investigations first published as papers, tables or charts in this volume the following are to be mentioned: (a) *The Historic Background of the Third International Congress of Eugenics*—From the study of first-hand documents the history of eugenics as an organized science was reviewed in special connection with its several meetings and exhibits of an international nature. The records show that, due largely to the influence of the Eugenics Record Office, the development of eugenics during the past 25 years has been soundly grounded on biology, and particularly on human genetics.

Close adherence has been kept to the basic principles of the science as founded by Galton, which science he defines as "The study of all agencies under social control which may impair or improve the racial qualities of future generations either physically or mentally." The development of eugenics has thus followed the line of study which concerns the inborn qualities—physical, mental and spiritual, both good and bad—of human family-stocks and human races. Essentially eugenics was found to differ from the improvement of plants and animals by better breeding, only in that the im-

provement of plants and animals by man is purely objective, while the improvement of man by himself is necessarily more subjective. Eugenics, as developed during the past generation, is the self-direction of human evolution.

(b) *Studies on leadership as a family-stock quality*—Among the family-history studies shown at this exhibit, and so first published, were eugenical studies of five families, each of which produced outstanding American leaders in some field of activity essential to national greatness. Most of the earlier studies of outstanding American families had been constructed on the genealogical rather than on the pedigree or biological basis. The two main difficulties, biologically, with the usual genealogical method of study, are that, in evaluating the hereditary stuff of a given individual, his collaterals are not given sufficient stress and his direct kin are treated along dilute and remote ancestral lines. As in the study of human degeneracy, human leadership is here worked out on the pedigree basis, that is, by first plotting the family tree covering the inborn qualities of the fifty or one hundred nearest blood-kin, both direct and collateral, of the propositus. The records show blood kinship and the possession, in kind and degree, of inborn qualities which work out in character and in personal capacities and shortcomings. The families here so studied, shown as exhibits and first published in "A Decade of Progress in Eugenics" were; (1) Pedigree of the Galton-Darwin-Wedgwood Family; (2) Family Stock of George Washington; (3) Abraham Lincoln: Family Stock Study; (4) The Near-Kin of Theodore Roosevelt; and (5) the Edison Family. Each of these family-history studies was constructed on the eugenical basis, that is, data descriptive of the physical, mental and spiritual qualities were collected for each of the immediate near-kin, both direct and collateral for the several generations closest to the particular subject. These data were analyzed primarily from the standpoint of genetics or natural inheritance. Also, in the field of personal achievement and defect, due consideration was made for the influence of environment. These several studies may be looked upon as typical of the new method of analysis of normal or talented families on the eugenical, the biological or the pedigree basis. Genealogy gives the family connections, the correct names and dates, but it is the task of human genetics to collect the essential data and to analyze the family history as a biological pedigree. Pedigree charts for degenerate families were worked out along these lines long before serious attempts were made in the biological analysis of the better family-stocks.

(c) *Race Integrity Standards*—In further collaboration with Dr. W. A. Plecker, Registrar of the Bureau of Vital Statistics of the Commonwealth of Virginia, studies were made on the race integrity laws of the several States, in particular reference to State legal barriers against miscegenation. It is generally recognized that, so far as the individual is concerned, the superficial biological criteria for determining slight traces of colored blood in a pass-for-white individual disappear while some colored blood actually may exist in the individual. The result is that resort must be had to pedigree-evidence. This is, of course, in keeping with the biological uses of pedigree-

evidence in all registered plants and animals. In Spanish America the Spanish-Indian cross which carries only $\frac{1}{8}$ Indian blood—the child of the Spaniard and the Castisa or $\frac{1}{4}$ Indian woman—is a pass-for-Spaniard. A Spaniard-Negro cross carrying $\frac{1}{8}$ Negro blood is called an “Albino.” An “Albina” woman mated with a Spaniard gives an offspring— $\frac{1}{16}$ Negro and $\frac{15}{16}$ Spaniard—called a Tornatro or a pass-for-Spaniard. In Jamaica the white-negro crosses which are diluted to $\frac{1}{16}$ black, by their own local connotation do not pass-for-white, but the $\frac{1}{32}$ and $\frac{1}{64}$ black bloods are pass-for-whites. Current studies now undertaken in collaboration with Mr. Stanton D. Wicks and Dr. W. A. Plecker, contemplate a further analysis of the legal, the popular, the genealogical, and the biological criteria for the more exact diagnosis of the “pass-for-white.”

(d) *Special Aptitude Test*—A specialized test for the sense of elegance, based on judgment of quality in furs, was worked out in the laboratory; tried in public tests for the first time at the exhibit of the Third International Eugenics Congress, and first published as Plate 28 in “A Decade of Progress in Eugenics.” The materials for this test comprise one 8 by 10 inch sample of each of ten different kinds and qualities of furs. The person being tested examines each sample critically with hand and eye, and then arranges the ten samples in descending order of his feeling and judgment of their quality. Public tests show that some persons trying the test tackle the job with interest and decision, while others show little comprehension. After balancing for training and experience, which are very important factors in this test, age and sex seem not so important as race and instinctive interest.

CURRENT MIGRATION STUDIES

The Second Pan-American Conference on Eugenics and Homiculture was held in Buenos Aires, Argentina, November 23 to 25, 1934 (immediately following the Ninth Pan-American Sanitary Conference which met in Buenos Aires, November 20 to 22). The First Pan-American Conference on Eugenics met in Havana, Cuba, in 1928, simultaneously with the Second International Congress of Migration, which latter was held under the auspices of the League of Nations. Among the scientific papers presented by the Carnegie Institution of Washington to the Buenos Aires conference was one on the “Basic Principles for a Common Pan-American Immigration-Control Policy.” From first-hand statistical reports it was shown that the several countries of the Western Hemisphere are still immigrant-receiving nations; that migration policy tends to special favor in permitting migration reciprocity within the Western Hemisphere; and that there is a tendency toward the development of a common immigration-control policy by the several Pan-American nations.

STERILIZATION FOR EUGENICAL PURPOSES

A new study has been made of the present legal status of sterilization in the various 48 states and the present trend of legislation in this particular field. Also the applications of sterilization statutes have been studied. There is noted an increase of operations performed each year since 1907 when the first

legal operation was performed in Indiana. The progress of the practice of sterilization is revealed by the total number of operations listed as on the following dates: January 1, 1921, 3233; July 1, 1925, 6244; January 1, 1928, 8515; December 1, 1931, 15,156; January 1, 1933, 16,688; January 1, 1934, 19,285; January 1, 1935, 21,539. Finally, the long-time effect of eugenical sterilization upon the individual has been considered. For this study 1200 case-history records are available. These cover the effects of the operation on the subject from the physiological, pathological, psychopathic and social points of view.

NUTRITION LABORATORY¹

FRANCIS G. BENEDICT, DIRECTOR

The nature of the Nutrition Laboratory's contributions to physiology is indicated by the titles of its papers published in scientific journals and its monographs issued in the last quarter of a century. Many of these contributions have dealt with the development of techniques, for in the field of bioenergetics, which has been the major field of investigation of the Nutrition Laboratory, progressive changes have had to be made in the experimental procedures employed. In the last fifteen years these modifications have all been made for the purpose of simplification of basal metabolism techniques. Now metabolism measurements formerly possible only in especially equipped, highly specialized laboratories can be made in any physician's office or on any field expedition into the most primitive environment.

Two recent developments will, it is believed, in due course of time be of even greater aid in widening physiological and clinical studies of metabolism. Thus, the perfection of a simple, direct-reading respiration apparatus, which was exhibited at the Carnegie Institution of Washington in December 1934, now makes it possible to determine the basal metabolism of a human being in twenty minutes, with no discomfort to the patient and by a technique that is rapidly acquired by non-technical assistants. As the use of this apparatus becomes more wide-spread, it is hoped that basal metabolism measurements will become a factor in every physical examination and an integral record in every family history of health. The second recent development is an apparatus for determining accurately and rapidly the maximum temperature of expired air. This apparatus, which was devised by the Director and Mrs. Cornelia Golay Benedict, was described at a meeting of the National Academy of Sciences in the fall of 1934. A lungful of air is completely expelled through a paper tube, and the temperature of this air is instantly recorded by the apparatus. The temperature of expired air has been found to be almost precisely one degree (Centigrade) below the simultaneously determined mouth, rectal, or so-called "blood" temperature. Such measurements should find use not in hospitals alone but in schools during seasons of cold epidemics. At such times each child, upon entering a school building, could be required to blow through a replaceable paper tube, and the normality or abnormality of body-temperature of each school child could thus be checked within only a few seconds. These two apparatus are simple in operation, are easily distributed in different localities, and should prove to have applicability in an ever widening circle. It is through such agencies that the Nutrition Laboratory's investigations can be of greatest immediate benefit to mankind.

Furthermore, with the perfection of Dr. Carpenter's technique for studying the respiratory quotient, the opportunity for accurate study of the qualitative nature of metabolic processes has never before been potentially so great as now. The respiratory quotient, that is, the ratio between the volume of carbon dioxide produced and the volume of oxygen absorbed by the body, gives information on the storage of glycogen, a most essential carbohydrate in the body, and hence of processes affecting its storage and depletion.

¹ Situated in Boston, Massachusetts.

In addition to the development of techniques, the researches in the fields of nutrition, metabolism and bio-energetics, all designed for betterment of knowledge of human physiology, have continued at the usual satisfactory rate. In the next few years emphasis is to be laid upon the analysis and the preparation for publication of the large amount of experimental material that has been accumulated, which will be useful from various standpoints. On every hand are unsolved problems of great importance to human physiology and pathology. Since the physiology of metabolic activity is better understood today by reason of the Nutrition Laboratory's researches, the greatest progress will undoubtedly be made in solving problems in human pathology, with the application of the techniques established by the Nutrition Laboratory and especially with the application of the valuable normal data that have been collected.

COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, has cooperated intensively in the study of large domestic animals, with special reference to the sheep, goat, pig, cow, steer and horse.

Dr. Oscar Riddle, of the Department of Genetics, is making considerable use of two forms of the four-chamber respiration apparatus for the study of the basal metabolism of pigeons and doves. This research plays an important rôle in his more extensive endocrine and racial studies. After a cooperation covering now a decade, our researches at Cold Spring Harbor have become so particularly identified with Dr. Riddle's own problems that the current year represents the last year of the Nutrition Laboratory's active cooperation with Dr. Riddle.

Dr. George L. Streeter, Director of the Department of Embryology, has supported strongly the research with the colony of *Macacus rhesus* at his department in Baltimore. The responsibility of this investigation, so far as the Nutrition Laboratory is concerned, has been taken over by Dr. T. M. Carpenter, who will be the associate in cooperation with Dr. Streeter in the future.

Professor H. C. Sherman, of the Department of Chemistry of Columbia University, continues his cooperative study on the problem of old age and metabolism of rats.

Dr. John M. Bruhn has cooperated with the Nutrition Laboratory in studying the infrahuman primates at the Yale Anthropoid Experiment Station, Orange Park, Florida. In this work he has benefited by the advice of Professor John F. Fulton of the Department of Physiology of Yale University, and of Professor Robert M. Yerkes. The cooperative research with Dr. Bruhn ceases in the current year, although he expects to carry on further investigations at Orange Park.

Dean Stanley D. Wilson, of the College of Natural Sciences, Yenching University, Peiping, China, has sent to the Nutrition Laboratory a large number of protocols of metabolism studies on Chinese, made by himself and his associates. The material now accumulated is so extensive and seemingly complete that the experimental side of the study has just been closed.

Professor Carey D. Miller, of the Department of Household Science of the University of Hawaii in Honolulu, has continued her studies of the metabolism of various racial mixtures and is at present on an expedition to Pago-Pago, American Samoa, to study the basal metabolism of some pure Polynesians. By mutual agreement, this particular cooperative research will be terminated in a few months.

Dr. Leonard Tarr, of the Montefiore Hospital, New York City, has been most active in his use of the Nutrition Laboratory's latest form of respiration apparatus for measurement of the metabolism of all patients entering hospitals. This apparatus was first introduced in the clinic of Professor L. Lichtwitz at the Montefiore Hospital, and Dr. Tarr has identified himself with an extensive series of comparisons of this form with other well-known forms of respiration apparatus.

As is customary, one of the Institution's biological conferences was held at the Nutrition Laboratory on January 5, 1935. Members of the Institution who were present were Messrs. F. G. Benedict, A. F. Blakeslee, T. M. Carpenter, W. M. Gilbert, C. G. Hartman, A. V. Kidder, H. H. Laughlin, R. C. Lee, E. C. MacDowell, O. Riddle and G. L. Streeter (chairman). In addition, Professor E. G. Ritzman of the University of New Hampshire and Dr. Milton O. Lee of the Harvard Medical School were in attendance. The researches of the Nutrition Laboratory and the cooperative studies at the University of New Hampshire were presented by local speakers. This annual meeting of the biological conference at the Nutrition Laboratory is particularly stimulating to the staff to present its unpublished material for comment and criticism. It is becoming increasingly evident that the visits of Carnegie Institution members are, both scientifically and administratively, the most helpful of all the visits received.

LECTURES AND STAFF NOTES

At a joint meeting of the Worcester Chapter of the Society of Sigma Xi and the Worcester Chemists Club in Worcester, Massachusetts, on March 12, 1935, Dr. Carpenter gave a talk on the "Investigations of the Carnegie Nutrition Laboratory on Basal Metabolism." At its annual meeting in May 1935, Dr. Carpenter was elected a National Councillor of the Northeastern Section of the American Chemical Society.

While visiting at the Yale Anthropoid Experiment Station, Orange Park, Florida, in November 1934, the Director spoke on "Body Temperature—Its Relation to Human and Animal Physiology." This was likewise the topic of a lecture given by him on November 21, 1934, at a meeting of the Western Reserve Chapter of Sigma Xi in Cleveland, Ohio. On December 16, 1934, he spoke at the Carnegie Institution of Washington on "A Simplified Respiration Apparatus for the Rapid Determination of Human Basal Metabolism." At a meeting of the American Philosophical Society in Philadelphia on April 19, 1935, a paper was presented by the Director entitled "Old Age Furnishes a Concept of Basal Metabolism" and at a meeting of the National Academy of Sciences on April 22 a paper entitled "The Lability of the Basal Metabolism of the Dairy Cow."

Following several months of severe illness and necessary retirement because of disability, our associate of many years, Mr. Edward L. Fox, died on December 19, 1934. Until the last he retained an active interest in the Nutrition Laboratory's affairs, and hardly a research in the Laboratory has not felt his absence, for his counsel and practical experience were invaluable. No staff member has ever left behind him a record of more consistent progress than has Mr. Fox.

INVESTIGATIONS IN PROGRESS

With the prospect of bringing to a close in two years the association of the Director of the Laboratory with its activities, pressure has naturally been brought to bear upon the necessity for preparing in advance the large mass of material accumulated and thus far unpublished in the last decade. Consequently the experimental activities have been somewhat curtailed, only one new project has been launched this year (the long planned-for study of the metabolism of the elephant), and stress is now being laid upon the secretarial, computing, tabulating and editing phases of our work.

THE CHEMICAL HYGROMETER

The development by Dr. T. M. Carpenter of a chemical hygrometer for the determination of the water-vapor content of air in respiration apparatus has been completed, and the apparatus has been put into practical use in studies of the water-vapor output of cows at the University of New Hampshire and of the elephant. The hygrometer was standardized by comparison with the absolute method and, in turn, has been used as a standardizing instrument for the delicate electrical psychrometer of Professor A. K. Noyons of Utrecht. The various tests were carried out with the assistance of Messrs. G. Lee, B. James and V. Coropatchinsky and Miss E. MacLachlan.

OBESITY IN MICE

In continuance of our observations on the fat mice of Dr. E. C. MacDowell, of the Department of Genetics, the metabolism was measured at 28° and at 16° C., to study the reaction of these well-protected animals to differences in environmental temperature. These experiments were carried out by R. C. Lee, and a simultaneous, careful study of both the rectal and skin temperature of these semi-poikilothermic animals was made by V. Coropatchinsky.

THE EFFECTS OF SUGARS ON THE RESPIRATORY EXCHANGE OF FAT MICE

In previous studies with men, canaries and rats the ingestion of the hexoses (glucose, fructose and galactose) was followed by respiratory quotients, the curves of which were characteristic for each species and not necessarily alike for all three groups. To determine whether the excessive weight acquired by the fat mice of Dr. MacDowell is due to a special type of metabolism, the respiratory exchange of these mice has been studied by Dr. Carpenter before and after the ingestion of glucose and fructose. As a control, similar studies have been made with common mice. The experiments have been carried out with the aid of B. James.

METABOLISM OF DOVES AND PIGEONS

The cooperative study of the metabolic differences associated with race, sex, age and hybridity has been continued by Dr. Oscar Riddle of the Department of Genetics, with the assistance of Mrs. G. C. Smith. The importance of adequate knowledge of basal heat production in his many races and hybrid types of doves and pigeons has been stressed by other studies which show that these types differ markedly in their response to prolactin and in the size of their germ glands during pre-adult life. The work of the past year has emphasized the need for repeating all measurements at various (high and low) temperatures. Alpha-dinitrophenol was found to stimulate heat production less at 15° than at 30° C. In a thyroidec-tomized pigeon, the drug had relatively little effect at either temperature.

METABOLISM OF THE NORMAL GOOSE

This animal, capable of living indefinitely without food and of being stuffed with large amounts of food, lends itself to a study of the so-called "specific dynamic action of foodstuffs," a study which has been actively furthered by R. C. Lee.

AVIAN THYROIDECTOMY

The successful removal of the thyroid glands of geese by Dr. Milton O. Lee of the Harvard Medical School has led to a series of observations on the effect of the absence of this gland upon basal metabolism and especially the reaction of the geese to cold. These studies have been conducted under Dr. Lee's counsel by R. C. Lee, aided by G. Lee and C. Hatch.

THE HIBERNATING MAMMAL

The profound alteration in vital activity noted with the woodchuck when either going into or coming out of hibernation has been further studied by R. C. Lee, with the assistance of G. Lee and C. Hatch. These studies promise to illuminate the unexplored field between the cold-blooded and the warm-blooded animal.

METABOLISM OF THE MACACUS RHEBUS

The measurements of the basal metabolism of this type of monkey have been continued by K. Koudelka in the Department of Embryology at Baltimore, under the supervision of Dr. T. M. Carpenter. The irritability and the extraordinary interest of these animals in the happenings in their environment have made the securing of really quiet periods of rare occurrence. This complication makes the interpretation of results over months and years difficult, especially with reference to the possible influence of changes in the sexual cycle and seasonal variations in the environment. This condition has necessitated the resort to the administration of a sedative immediately preceding the measurements of basal metabolism. Preliminary experiments with various amounts of nembutal at different intervals before the measurements began have had as a result the application, immediately preceding the measurements, of a standard dose according to body-weight. As no apparent effect of the drug on the basal metabolism has been

found, this procedure makes it possible to have periodic determinations of basal metabolism on a comparable basis so far as absence of activity is concerned. Indirectly the observations also contribute information regarding the use of drugs in the study of metabolism. The investigation is being made with the cooperation of Dr. George L. Streeter and Dr. Carl G. Hartman of the Department of Embryology, and frequent conferences with them have helped to clarify the rather obscure studies.

METABOLISM OF THE CHIMPANZEE

In the cooperative research at the Yale Anthropoid Experiment Station, Dr. J. H. Bruhn has especially studied the oestrus cycle of the chimpanzee. The large number of young born at the Station have also afforded special facilities for studying the factor of growth.

METABOLISM OF LARGE DOMESTIC ANIMALS

Perhaps no one research of the Nutrition Laboratory has occasioned more general interest than the experiments on large domestic animals, carried out in cooperation with Professor E. G. Ritzman of the University of New Hampshire. The experiments this year have included studies of the water-vapor output of cows and the methane production of an adult horse and an adult pig. In continuance of the research on the variability in the metabolism of dairy cows, observations have been made to study the basal metabolism after feeding on concentrates alone, after pasture feeding, and after feeding dry hay during barn confinement as compared with feeding dry hay during outdoor life (free exercise and exposure to sun, wind, and rain, but no access to grass). In these investigations Professor Ritzman has been aided by Mrs. H. H. Latimer, N. F. Colovos, A. D. Littlehale and L. E. Washburn.

METABOLISM OF THE ELEPHANT

Following definitely laid plans that have been nearly twenty years in maturing, a study of the gaseous metabolism of one very large elephant and other physiological observations on several herds of circus elephants were undertaken. In this research invaluable assistance was given by R. C. Lee, aided by G. Lee and C. Hatch. A most careful chemical study of elephant's urine has been begun by Dr. Carpenter, with the effective aid of Miss E. MacLachlan. In chemical and microscopical examinations of urine and feces we were helped greatly by Dr. E. P. Joslin, Dr. H. F. Root and Dr. A. Marble at the New England Deaconess Hospital, Boston. Other specimens of feces and urine were carefully examined in the laboratory of Dr. H. E. Thompson of the Eastern Maine General Hospital, Bangor, Maine. Thanks to the kindness of Dr. W. N. Miner of the Calais Hospital, Calais, Maine, his associate, Dr. Kenneth Russell, examined certain specimens of urine and feces. A summary of the findings is now being prepared in monographic form.

STUDIES OF FOOD MATERIALS OF PRIMITIVE PEOPLES

The study of the food of the Maya in Yucatan, based on food samples collected by Dr. Morris Steggerda of the Department of Genetics, has

been continued. In addition, samples of the food of the Navaho Indians have been secured by Dr. Steggerda for analysis, and Dr. S. D. Aberle, Research Associate of the Institution, has collected samples from the Pueblo Indians.

EFFECT OF GALACTOSE AND LACTOSE ON ALVEOLAR CARBON DIOXIDE OF HUMANS

As a contribution to the interpretation of the extraordinary rise in the respiratory quotient after the ingestion of galactose by human subjects, the respiratory quotient and the alveolar carbon dioxide have been further studied (in parallel) by Dr. Carpenter before and after the ingestion of galactose, lactose, and glucose and galactose together, with the man who has been the subject in many preceding studies in this Laboratory. The experiments were made with the assistance of B. James and Miss E. MacLachlan.

EFFECT OF VOLUNTARY OVERVENTILATION IN BREATHING ON HUMAN RESPIRATORY EXCHANGE

The opinion is occasionally expressed in the interpretation of high respiratory quotients that they are due to overventilation, "Auspumpung." If this is so, one would expect the following respiratory quotients to be compensatingly lower. To determine what the effect on the respiratory quotient is of voluntarily excessive breathing, the respiratory exchange has been measured by Dr. Carpenter with a human subject in periods before, during, and following short periods of voluntary overbreathing. The experiments were carried out with the assistance of B. James and Miss E. MacLachlan.

METABOLISM DURING OLD AGE

The Nutrition Laboratory's human studies on old age have been supplemented by the cooperative research with Professor H. C. Sherman of Columbia University on the metabolism of a series of rats kept until death in his colony. A four-chamber respiration apparatus has been installed at Columbia University, and the observations are being made with the skillful assistance of Miss A. Zmachinsky.

EDITORIAL AND LITERARY WORK

Several manuscripts have been in process of preparation during the year and have either been accepted or are ready to be submitted for publication. These are:

A chemical hygrometer for respiration apparatus. (T. M. Carpenter.)

The effect of glucose on the metabolism of ethyl alcohol in man. (T. M. Carpenter and R. C. Lee.)

The food of the present-day Maya Indians of Yucatan. (F. G. Benedict and M. Steggerda.)

Basal metabolism and urinary nitrogen excretion of Oriental women. (A. H. Turner and F. G. Benedict. *Amer. Jour. Physiol.*)

The plans for writing that have been undertaken and will continue during the coming two years are calling for much editorial work on the part of the

Editor, Miss Elsie A. Wilson, and have made necessary the reviewing of a great deal of literature. We have been particularly fortunate in having associated with us as *littérateur* Dr. Blanche B. Daly, formerly instructor in physiology at Hunter College, New York City.

PUBLICATIONS

- (1) *Voluntarily induced increases in the rates of certain "involuntary" physiological processes of a human subject.* T. M. Carpenter, R. G. Hoskins and F. A. Hitchcock. *Amer. Jour. Physiol.*, vol. 110, pages 320-328 (1934).

Appreciable increases in oxygen consumption, heart-rate and blood-pressure above the rates obtaining under basal conditions were voluntarily produced by a human subject without apparent visible effort and independent of emotion. How the augmentation of these various "involuntary processes" was induced is difficult to explain. Only when the subject lay practically nude was it possible to detect any indication of effort (increased muscle tonus) on his part. Under the ordinary conditions of measurement of basal metabolism, that is, with the subject clothed or covered with a blanket, the causes for the increased values would have remained obscure. The experiments demonstrate that significant increases in physiological processes can be brought on and sustained for periods as long as would be used in ordinary measurements of basal metabolism. The metabolic rate measured under the usual prescribed basal conditions is therefore not always necessarily the basal rate.

- (2) *The effect of hexoscs on the metabolism of alcohol in man.* Thorne M. Carpenter, Marion Buidett and Robert C. Lee. *Amer. Jour. Physiol.*, vol. 109, page 18 (1934).

Abstract of a paper read at the Annual Meeting of the American Physiological Society in New York City, March 1934. The rate of disappearance of alcohol from expired air and the course of the respiratory quotient were studied with a human subject for at least three hours after ingestion of alcohol alone and after alcohol with an iso-molecular quantity of glucose, fructose, or galactose.

- (3) *The influence of previous diet, growth and age upon the basal metabolism of the rat.* Kathryn Horst, Lafayette B. Mendel and Francis G. Benedict. *Jour. Nutrition*, vol. 8, pages 139-162 (1934).

Continued feeding of a synthetic diet did not markedly alter the basal metabolism of male rats. With diets of high and medium protein content there was practically no difference in the metabolism, but with a low-protein diet the metabolism was lower and a deleterious physiological effect of the diet was indicated by post-mortem examinations. Young rats, stunted in growth, had a lower heat-production than normal rats of the same age but greater weight or of the same weight but different age. Realimentation resulted in resumption of normal growth, and when normal growth was attained, the basal metabolism was much the same as that of the normally growing rat of the same age and weight. Rate of growth, whether slow or rapid, had no appreciable effect upon the metabolism. Adult males had a higher metabolism than females of the same age. The heat production of both sexes remained at practically a constant level during the second and third years of life, contrary to earlier observations on females from a different rat colony.

- (4) *Degree of constancy in human basal metabolism.* Francis G. Benedict. Amer. Jour. Physiol., vol. 110, pages 521-530 (1935).

With a well-conditioned man in complete muscular and mental repose and 12 hours after food, the oxygen consumption, respiratory quotient, pulse and respiration rates, body-temperature and insensible perspiration were extraordinarily uniform from day to day over a period of a month. These physiological functions were not affected by variations in the length and depth of sleep, the usual fluctuations in room-temperature, and considerable variations in the character and amount of the food eaten on the evenings preceding the measurements. The insensible perspiration was closely correlated with the basal heat-production. An emotional disturbance caused a marked increase in metabolism, which did not subside for several days.

- (5) *The influence of breathing oxygen-rich atmospheres on human respiratory exchange during severe muscular work and recovery from work.* Francis G. Benedict, Robert C. Lee and Fritz Strieck. Arbeitsphysiologie, vol. 8, pages 266-303 (1934).

Inhalation of oxygen-rich air had no effect on the respiration-rate during rest or work (riding a bicycle ergometer), but lowered the heart-rate under both conditions. No effect upon the oxygen consumption either at rest before work, during work, or during the recovery phase was noted. The rate of recovery was the same, irrespective of the oxygen content of the air breathed. The character of the material burned in the body during muscular effort, as indicated by the respiratory quotients, was not altered by the inhalation of highly oxygenated air. A technique is proposed for measuring the oxygen consumption during the recovery phase following work, to enable the prediction of the probable oxygen consumption during the immediately preceding work.

- (6) *Die Oberflächenbestimmung verschiedener Tiergattungen.* Francis G. Benedict. Asher-Spiro's Ergebnisse der Physiologie, vol. 36, pages 300-346 (1934).

An analysis is made of the methods employed in measuring the surface areas or skin areas of different species of animals and the values derived therefrom for the constant K in the formula $S = K \times w^{2/3}$. This analysis includes a survey of the literature on this subject through the year 1933. All species of animals upon which body-surface measurements have been made are considered, including both warm-blooded and cold-blooded. It is concluded that the surface area of any animal, the weight of which is known, can be computed with a sufficient degree of accuracy by multiplying the two-thirds power of the body-weight in grams by 10. The accuracy of this calculated area will be in general far greater than that of the metabolism measurements that are to be compared.

- (7) *The physiology of extreme old age.* Francis G. Benedict and Howard F. Root. New Eng. Jour. Med., vol. 211, pages 521-536 (1934).

This report gives the details of a comprehensive physiological and clinical study of a 91-year-old man, including complete physical and neuro-psychiatric examinations, urine analyses, and measurements of the skin temperature, insensible perspiration and basal metabolism. Comparison of this man's heat-production with that of other men of about the same age is made.

- (8) *Vereinfachte Messung des Atmungs-Stoffwechsels.* Francis G. Benedict. Wiener Archiv für innere Medizin, vol. 27, pages 1-22 (1935).

A simplified, closed-circuit respiration apparatus is described, which contributes to the greater comfort of the subject, employs a direct-reading

instrument that eliminates the necessity for calculation of results, and enables rapid measurements (15 to 20 minutes) of basal metabolism with a satisfactory degree of accuracy. The apparatus is recommended for orientation measurements in hospitals, for physiological surveys in schools and universities, and for tests of physical fitness when group life insurance or social welfare supervision is contemplated.

- (9) *Lability of the basal metabolism of the dairy cow.* Francis G. Benedict and Ernest G. Ritzman. *Proc. Nat. Acad. Sci.*, vol. 21, pages 304-308 (1935).

The metabolism of cows measured on the fourth and fifth days of fasting, after maintenance feeding on roughages alone, concentrates alone, or green grass, was not constant for any appreciable length of time. In some instances a marked change in the fasting metabolism (either a decrease or an increase) of from 30 to 85 per cent occurred within two months. The greatest changes in metabolism occurred during lactation and especially with the transfer from hay to pasture feeding or *vice versa*. In view of the lability of the basal metabolism of these dairy cows, the concept of constancy in basal metabolism of animals must be revised and the possibility should be recognized that great changes in endogenous metabolism can take place within a relatively short time without concurrent changes in body-weight.

- (10) *Old age and basal metabolism.* Francis G. Benedict. *New Eng. Jour. Med.*, vol 212, pages 1111-1122 (1935).

Observations on elderly women lead to the concept that the total 24-hour basal heat-production of all normal elderly women above 66 years of age, whose vigorous physical activities have ceased, is at a constant low level of about 1030 calories. It is furthermore conceived that the basic daily energy requirement of every normal woman may be 1030 total calories, that at the older ages this basic requirement will be increased or decreased by gross over- or under-weight, and that at younger ages it will be increased for the greater energy needs of youth, growth, reproductive activity and greater physical activity.

TORTUGAS LABORATORY

W. H. LONGLEY, EXECUTIVE OFFICER

VISITING INVESTIGATORS

The Laboratory was open this year for the usual period of 12 weeks. During the season the following investigators worked upon the subjects and for the times indicated:

- D. E. S. Brown, New York University Medical School. Cellular reactions to high hydrostatic pressures. July 31 to August 26.
- W. E. Bullington, Randolph-Macon College. Morphology and taxonomy of ciliate protozoa. July 31 to August 26.
- H. H. Darby, Bartol Foundation. Regeneration and differentiation in decapod crustacea. June 5 to August 12.
- W. L. Doyle, Johns Hopkins University. Zooxanthellæ. June 5 to July 15.
- I. Gersh, Johns Hopkins Medical School. Anterior pituitary gland of the nurse shark. July 31 to August 26.
- H. B. Goodrich, Wesleyan University. Color patterns of fishes. July 17 to August 26.
- Caswell Grave, Washington University. Ascidian metamorphosis. June 19 to July 31.
- J. E. Harris, Cambridge University. Anatomy and physiology of the pectoral fin. June 5 to July 15.
- M. J. Kopac, National Research Fellow. Intracellular pH determinations on marine ova. July 17 to August 26.
- Gordon Marsh, University of Iowa. Effects of temperature and light upon the inherent potential of *Valonia*. June 5 to July 15.
- Paul A. Nicoll, Washington University. Ascidian metamorphosis (with Dr. Grave). June 19 to August 26.
- R. G. Stone, University of Kansas City. Regeneration in *Ptychodera* and annelids. June 5 to August 12.
- D. H. Tennent, Bryn Mawr College. Photodynamic properties of vital dyes. July 17 to August 26.
- Shigeo Yamanouchi, University of Chicago. Life histories of marine algæ. June 5 to July 15.
- W. H. Longley, Goucher College; Executive Officer of Laboratory. Taxonomy and anatomy of fishes. June 5 to August 26.

In addition to investigators named above, R. H. Chase and D. M. Tennent acted, respectively, as assistants to Doctors Darby and Tennent.

Dr. Brown's findings include several points in the special field of muscle physiology. His preliminary attempt to secure material for study from deep water will be followed, it is to be hoped, by others under more favorable conditions. His answer to the question of the way in which animals of the cold deep sea achieved their complex adaptation to temperature and pressure conditioning their muscular responses will be awaited with interest.

Dr. Darby's effective analysis of the process of differentiation, as illustrated in certain crustacean chelæ, proceeds with gratifying success, exhibiting it in clearer light than has surrounded the subject before. A new concept introduced in the physiology of hormones merits the attention of students in that field.

Dr. Grave's and Mr. Nicoll's discovery that even in very dilute solution salts of certain heavy metals are highly effective in inducing normal meta-

morphosis raises new questions, to be answered at last, probably, only by spectrographic methods of analysis. Dr. Gersh's study of the distribution of function among cells of the anterior pituitary gland in the nurse shark affords welcome opportunity of collaboration with the Department of Genetics through biological assay to be undertaken there. Observations upon *Valonia* by Dr. Marsh suggest the necessity of adequate control of temperature and illumination in any work upon it which involves the inherent potential across its protoplasmic layer.

The photodynamic effects of certain vital dyes, upon which Dr. Tennent reports, are striking, whether one considers the exceedingly slight concentrations of the solutions in which they sometimes appear or the intensity with which they may manifest themselves. His investigation, in a sense complete in itself, directs attention inevitably to possibilities yet to be realized: those of learning more of the nature of mitosis through study of conditions so profoundly affecting it and of destroying by light in the living body morbid growths differentially stained.

Almost from the beginning of the season, illness prevented Dr. Yamaguchi's putting into effect a program it is hoped he may complete successfully another year.

For the loan of 125 mg. of radium by the Radium Chemical Co., through the Radiation Committee of the National Research Council, investigators whose researches were advanced by its use and the Laboratory are alike grateful. It is also a pleasure to acknowledge indebtedness to Dr. Edwin H. Carnes, Surgeon-in-charge, of the Marine Hospital, Key West, for assistance in emergency, and to the Lighthouse Bureau for the privilege of radio communication with the mainland by way of the office of the Superintendent of the 7th Lighthouse District, Mr. W. M. Demeritt.

INVESTIGATIONS

Cellular Reactions to High Hydrostatic Pressure, by D. E. S. Brown

During the present session an investigation of deep sea and tropical shallow water vertebrates and invertebrates was carried on by methods developed in previous studies upon the muscles of temperate forms.

The work on deep-sea types was considerably restricted by weather conditions, but sufficient material was obtained to prove the feasibility of a physiological study of the material. Spider crabs (to be identified) collected in 100 fathoms and immediately placed in sea-water at 5°C. survived for two days in the laboratory. The claw muscle of these, as well as of swimming crabs collected at 80 fathoms and similarly treated, were subjected to pressures from 68 to 400 atms. and their contractions recorded. Specimens collected at 200 fathoms (pressure 35 atms.) failed to survive in cold sea-water although their tissues were in good condition when brought aboard. A batfish (*Dibranchius*) taken at 200 fathoms showed no reflex activity, but dissection revealed the heart beating regularly. In general, the immediate effect of the decompression is to abolish central nervous function—the independent functions of the tissues undergoing no serious impairment. In view of this behavior, it is evident that future studies on material from depths greater than 150 fathoms must be carried out at sea at the time of capture. This will entail experiments of two types:

(a) The response of the animal to temperature and pressures similar to those obtaining normally. This will involve the construction of a suitable pressure chamber.

(b) The response of isolated muscle to a wide range of temperature and pressure, employing pressure equipment already available.

The action of pressure upon a pectoral fin muscle of the red grouper (*Epinephelus morio*) was investigated over a temperature range from 10° to 30°. The muscle immersed in a balanced salt solution was subjected to pressures from 68 to 204 atms. and the contractions recorded by an optical method.

The results of this study show clearly that at temperatures below 14° to 16°, pressure causes a decrease in the size of the contraction, while at higher temperatures the contraction is increased. At 14° to 16°, therefore, the size of the contraction is not altered by pressures from 8 to 204 atms. In frog muscle a similar situation obtains at 5° to 6° and it seems clear that this difference in the critical temperature is related to the normal temperature range of the animal—the grouper living at an average temperature of 25°, the frog at an average temperature of about 16°. The fact that the critical temperature shifts in this manner strongly suggests that pressure is acting indirectly upon the chemical processes in the cell through its general effect upon cell processes, rather than directly affecting some specific chemical process which proceeds only as a function of pressure and temperature.

In relation to the more general question of environmental adaptation, the results show that in the first instance the adaptation to high pressure involves concomitant adaptation to temperature. It is certain, however, that adaptation to pressure at a comparatively constant temperature (1° to 4°) occurs as evidenced by the deep-sea forms. The mechanism of this process must await a study of sub-arctic shallow and deep-water forms.

The action of pressure upon the leg muscles of a spider crab, two species of swimming crabs, and the spiny lobster was investigated. The striated muscle of these forms exhibits two types of contraction, a very rapid twitch-like contraction and a slow contraction resembling somewhat a contracture. At 30°, pressures from 68 to 400 atms. were found in each instance to decrease the fast contraction, but to increase the slow one. This is the first evidence of a differential effect of pressure upon the release of energy in contraction and offers a possibility of defining the genesis of the two contraction types.

Experiments performed with pressure upon the smooth muscle from the mantle of the sea slug (*Aplysia protea*) yield clear evidence of an increase in the size of the contraction at pressures from 68 to 200 atms. Previous studies upon smooth muscles of vertebrates show a decrease in the contraction under pressure. The present results present an interesting exception and further experiments are necessary to clarify the situation.

Morphology and Taxonomy of Ciliata, by W. E. Bullington

During the summers of 1930 and 1931, while studying spiraling in Ciliates, particularly of the genus *Frontonia*, at the Tortugas Laboratory, I found several species which apparently had never been described. Sketches of these were made and information on structure and locomotion secured and tabulated for future use. This summer I have attempted to find again as

many of these as I could, to check data in hand, and to secure additional information required in their description.

About 20 have now been studied and drawn to scale. One at least seems to fit in no previously described genus; the others belong to the well-known genera *Coleps*, *Ophryoglena*, *Strombidium*, *Trachelocerca*, *Oxytricha*, *Condyllostoma*, *Uncinata*, *Peritromus* and *Stentor*.

Studies on Crustacean Development, by H. H. Darby

Previous studies on the nature of the regenerative processes in *Crangon armillatus* were continued. It has already been shown that when both the pinch-claw and the snap-claw of this animal are removed in the order named, with a sufficient length of time between, the side which originally carried the pinch-claw has a start in growth ahead of the other and so obtains the snap-claw on regeneration. Studies were continued on the relation of temperature to the length of the start in growth that a regenerating pinch-claw must have over a regenerating snap-claw in order to obtain the material necessary for producing a snap-claw. At 22°C., the pinch-claw side needs a start of about 80 hours ahead of the snap-claw side in order to produce reversal of the chelæ; whereas at 35° C., a start of 26 hours will produce a good percentage of reversal. In view of the magnitude of the temperature effect, rigid control of this factor is obligatory for further studies of the phenomena associated with reversal.

The hypothesis that the making of a pinch-claw into a snap-claw is due to a sexual hormone (chelin) was further supported. Previous work had shown that chelin was produced discontinuously and in small quantities, and that it was drained off (i.e. permanently removed from circulation) in the process of differentiating a pinch-claw into a snap-claw. Further confirmation of this concept was obtained by repeatedly removing the claw about to become a snap-claw. This treatment had the following result: that the animal, although normal in all other respects, finally produced only pinch-claws and remained in that condition over several molts. In the light of these results, the concept of the existence of negative hormones which prevent the ordinary hormones from acting can be seriously challenged, and a simpler concept substituted, namely, that hormone deficiency results from an exhausted condition of the cells responsible for hormone production.

The remodeling of the pinch-claw into a snap-claw which follows snap-claw removal in this organism was studied. The snap-claw was removed and at the same time a small piece of the dactylus of the remaining pinch-claw was taken off. At the next molt the pinch-claw became a snap-claw, but the piece of the dactylus which had been removed was missing from the newly formed snap-claw. This showed conclusively that each part of the pinch-claw is remodeled into a corresponding part of the snap-claw, and that no mass remodeling takes place. By the use of this procedure—removal of the snap-claw and the performance of operations of varying extent on the pinch-claw—the controlling area of growth was shown to be out at the ends of the claws. Removal of both tips of the pinch-claw at the level of the joint of the dactylus caused the growth of the regenerating tips to be equal to the growth at the base of the whole claw regenerating on the other side, with the end-result of an animal with two perfect snap-claws of entirely different sizes. This shows that the snap-claw is made by the addition to the pinch-claw of definite formative material. This addition takes place throughout the last two joints of the appendage.

Reversal of chelæ in the ghost crab, *Ocypoda albicans*, was obtained by removing the smaller claw (analogous to the pinch-claw in *Crangon*) and later the larger claw, after an interval of 2 weeks. This is another application of the concept that a head start plays the important rôle in determining which side is to obtain the more highly differentiated claw. In *Ocypoda*, removal of the large claw alone is not followed by reversal; but if two new growing centers are established by removing both claws, and the small side is given sufficient start over the large, the new large claw will now appear on the side which previously carried the small claw. The reversal thus obtained is entirely comparable with the condition in *Crangon*.

Another series of experiments was set up to demonstrate the difference in production of chelin at different temperatures. Animals with two snap-claws (produced experimentally) were kept at 22° and at 35° C. For the 22° experiment, animals with perfect snap-claws were used. After the first molt, they still had one perfect snap-claw, but the other was intermediate between snap-claw and pinch-claw. At the second molt, they reverted completely to their natural condition, with one snap-claw and one pinch-claw. For the 35° experiment, animals with imperfectly formed snap-claws were selected; that is, either one snap-claw was larger than the other, or both were incompletely differentiated. At the next molt both claws became perfect snap-claws, even though the size difference persisted in some cases. In experiments reported previously, it has not been possible to determine whether the improvement in snap-claw formation observed at high temperatures was due to increased production of chelin or better utilization of chelin. In the above experiments it is clearly shown that it is the production, not the utilization, of the hormone that is enhanced by high temperature. The regression from two snap-claws to one snap-claw and one pinch-claw is exactly comparable with the regression of the comb in capons to its original size, when administration of the hormone which induces comb growth is stopped. In the present experiments, low temperature permitted the animal to make only enough hormone for the maintenance of one snap-claw.

The equivalence of retardation of growth by radium and by low temperature was investigated, and it was found possible to determine biologically a thermal equivalent for a given amount of gamma radiation.

Huxley and Dawes have suggested that the reason why the snap-claw differentiates from the pinch-claw is that it has a higher relative growth-rate than the other claw and therefore takes for itself more of the substrates for growth. In a limited sense this is true, as I have already shown that the claw which arrives first at a given stage of development becomes the snap-claw; but differentiation can not be a direct result of growth *per se*, because it is possible to produce animals with the pinch-claw larger than the snap-claw. Not only is this dissimilarity of size evidence against Huxley's idea; it can also be shown that a pinch-claw with a small piece removed can become a snap-claw, and at the same time a whole new snap-claw be regenerated on the opposite side. The problem of relative growth has also been investigated from other aspects, with results which do not support Huxley's hypothesis.

Observations on Zooxanthellæ, by W. L. Doyle

In continuation of cytological studies on the foraminifera, the nature of the symbiosis between these organisms and the zooxanthellæ they contain was investigated in *Orbitolites duplex*. The effects of changes in environmental

conditions (light, intensity and wave-length; hydrogen-ion concentration; carbon dioxide and oxygen tension) on the cytoplasmic constitution of the zooxanthellæ were ascertained by histochemical methods and camera lucida drawings showing variations in quantities of the various components.

Depending on the milieu, the following structures were found in the zooxanthellæ, a plastid (composed of a colorless central pyrenoid surrounded by an amyloid layer), amyloid grains, an "assimilation product" of uncertain composition and similar in certain respects to "Golgi substance," oil droplets, red-pigment granules, crystals of calcium oxalate, and the regularly occurring nucleus, cellulose wall and hyaline cytoplasm.

Zooxanthellæ which have been in light of normal¹ intensity either in the moat at Fort Jefferson or in the laboratory contain a plastid, a few calcium oxalate crystals, a small assimilation product and several small oil droplets. If the intensity of the light is high, the amount of amyloid material surrounding the pyrenoid of the plastid increases and additional amyloid grains form, the oil does not change greatly in amount, the calcium oxalate crystals decrease and finally disappear and the assimilation product decreases.

If the intensity is low, the amyloid material disappears and the plastid no longer stains with iodine, the oil droplets present become larger, the calcium oxalate increases in amount, the assimilation product becomes very prominent and red-pigment granules appear.

Correlated with these changes in the cytoplasm of the zooxanthellæ are changes in the cytoplasm of the foraminifera. Conditions resulting in formation of large amounts of calcium oxalate or amyloid material in the zooxanthellæ result in increase of calcium oxalate or amyloid material, respectively, in the foraminifera.

In specimens kept in normal light under increased carbon dioxide tension, amyloid material increases greatly and the calcium oxalate disappears rapidly. In specimens kept in darkness under similarly increased carbon dioxide tension the amyloid material does not increase and the calcium oxalate does not decrease. In normal and high intensities, slight increase in carbon dioxide tension results in more rapid increase in amyloid material than does great increase in carbon dioxide tension.

Regardless of light intensity, increased carbon dioxide tension results in solution of the shell of the foraminifera without injury to the organism. Specimens from which the shells had been removed in this manner were used in observations on redeposition of the shell. In dim light a new shell is formed in two weeks.

In specimens kept in darkness in sea-water saturated with hydrogen the amyloid material and the calcium oxalate do not noticeably change in amount.

In specimens kept in comparable intensities of light of different wave-lengths no amyloid material is produced unless red light (6500 to 7000 Å.) is present above a definite minimal intensity. In much higher intensities of other wave-lengths no amyloid material is produced.

The effects of variation in light intensity on the structure of the zooxanthellæ in the corals, *Orbicella*, *Acropora*, *Meandrina*, *Platygyra* and *Porites*; the protozoan, *Folliculina*; and young *Cassiopea* (medusa) were found to correspond with those obtained in *Orbitolites*.

¹The intensities of the light used are being calculated. For the present they will be referred to as low, normal and high.

The Eosinophile Cells of the Anterior Pituitary Gland of the Nurse Shark,
by I. Gersh

The object of experiments planned is to determine which of the activities of the anterior pituitary gland are referable to the eosinophile cells. Only in the shark are these separable from the basophile and chromophile cells, because of their rather sharp localization. To determine the precise limits within which they are segregated, six fresh glands were fixed for histological examination. Fifteen others were preserved in acetone for biological assay. Embryos were also preserved for study of the development of the gland.

Studies on Color Patterns of Tortugas Fish by H. B. Goodrich

The aim of these studies has been to investigate internal conditions which may control the development and maintenance of color patterns in fish. The work undertaken at Tortugas is a continuation of studies made on certain fresh-water fish. These fish, however, and certain marine forms do not provide entirely suitable material for the purpose. On this account the opportunity to study the brilliantly patterned coral reef fish has been especially welcome.

The method employed has been to transplant tissues from one type of pigmented area to another. This was done in order to test whether or not a tissue of one color can grow and maintain itself in a location characterized by a different pigmentation. The technique in fish is simple because the transplantation can be easily effected by transferring scales with adherent tissue from one scale pocket to another. The scales are trimmed at the base and inserted slightly deeper in the new pocket than in the original pocket in order to facilitate the adherence of tissues. Asepsis is not required.

Halichæres bivittatus (Bloch) and *Thalassoma bifasciatum* (Bloch), known, respectively, by the common names of "Slippery Dick" and "Blue-head," were selected as favorable forms for study. The first has proved to be the most useful.

Halichæres shows longitudinal dark and light stripes. Transplants have been made between these stripes and also, as controls, transplants have been made within each stripe. Observations were made at intervals on the scales *in situ* on anesthetized fish and at the close of the experiment the scales were removed and counts were made of the chromatophores. Some evidence found indicates that for a time there exists a post-operative effect causing a decrease in the number of pigment cells, but that eventually the pigmentation of the tissue approximates that of the new environment. There is probably an invasion of cells from surrounding tissues, but much of the old tissue must remain for at least thirty days and probably much longer.

Transplants between different individuals were also made. The results confirm previous observations of the writer to the effect that these are in no cases so far observed found to be successful. The tissues show necrosis and degenerate.

In *Thalassoma* tissue changes progress much more slowly and possibly retain their original characteristics indefinitely. Scales removed at the conclusion of experiments that were continued as long as the season allowed showed essentially their original characteristics.

Various observations were made on the chromatophore complexes which produce the different colors. In *Halichæres*, for example, counts on one set of scales gave the following approximations:

Number of chromatophores per square millimeter of surface

	Dark stripe	Light stripe (yellow area)
Melanophores . . .	585	48
Erythrophores .	1,190	0
Xanthophores	0	387
Iridiocytes . .	3,650	4,930

Similar observations have been made on the black, blue and green areas of *Thalassoma*. Here not only the relative numbers but also the grouping of cells play a part in the production of the optical effect. In the blue zone the iridiocytes are clustered about and above individual melanophores, while in the black and green zones this clustering is much less noticeable.

Further Studies of Ascidian Metamorphosis, by Caswell Grave and Paul A. Nicoll

From previous work (Year Book No. 32, 1933, 268-271) it is known that metamorphosis of the larvæ of *Phallusia nigra* and *Polyandrocarpa tinctoria* is accelerated by many substances. This year an intensive study has been made of the effect upon them of amino-acids and related compounds, of tissue extracts and salts of heavy metals.

Amino-acids and related compounds—l-histidine, leucine, glycine, cysteine, d-l-alanine and reduced glutathione, in equivalent SH concentrations to cysteine, were all effective in accelerating metamorphosis of both species. The effective concentration-range varies between 1×10^{-3} to 1×10^{-5} grams per cc. causing acceleration to 100 per cent over controls in experiments of five hours duration. Concentrations between 1×10^{-4} and 1×10^{-5} tended to be the most effective, but no clear relationship was demonstrated between concentration and effect with any amino-acid, probably on account of individual variability of larvæ in the time of appearance of susceptibility to metamorphosis. On the other hand, tryptophane, d-l-phenyl-alanine, tyrosine, l-aspartic and d-glutamic acids, d-arginine and cystine, as well as diiodotyrosine and reduced glutathione in concentrations equivalent by weight but not equivalent in SH values to cysteine, gave percentages of metamorphosis not significantly higher than occurred in controls. Concentrations used and duration of experiments were the same as in the first group of acids. In all cases the pH of the solutions was carefully controlled by means of the glass electrode, the final pH of all test solutions being approximately that of unmodified sea-water. No significant change in pH value took place during experiments.

Tissue extracts—Extracts found most effective in accelerating metamorphosis are those made from the mantle, atrium or pharynx of adult ascidians or from free-swimming larvæ or from developing embryos and their enveloping chorionic membrane at and after a stage reached near the fourth hour of development. Extracts made from unfertilized eggs of *Phallusia* or early stages of developing embryos had a toxic effect on larvæ of the same species. With further development, this toxicity diminished; then followed stages that yielded an extract neither toxic nor accelerating in effect. The stage at which the accelerating substance is differentiated was

reached between the third and fourth hour after fertilization. The extract made from embryos at this stage induced metamorphosis of *Phallusia* larvæ to the extent of about 85 per cent over controls. Extracts made from later stages showed a potency only slightly increased. The abruptness of the appearance of the accelerating substance in full strength is strikingly evident. Tissue extracts which showed no accelerating effect on metamorphosis of either *Phallusia* or *Polyandrocarpa* larvæ were made from mantle-atrium tissue of two species of simple ascidian, from the visceral mass (glandular and without muscle fibers) of adult *Phallusia* and from skeletal muscle of the cray-fish. An extract of the skeletal muscle of a teleost (gray-snapper) accelerated metamorphosis of *Phallusia* larvæ to the extent of about 50 per cent in a period of five hours, the control showing slightly over 4 per cent. This is to be compared with 100 per cent induced in larvæ of the same lot by *Phallusia* mantle extract in two hours.

After mincing it finely with scissors and drying it between sheets of filter paper, all extracts were made by grinding the tissue in 10 cc. of the solvent (sea-water, distilled water, alcohol, acetone, ether, chloroform, benzene) per 500 mg. of tissue. In the case of extracts of *Polyandrocarpa*, 300 mg. of entire colony substance per 10 cc. of the solvent were used. When tissues were extracted with fat solvents, the filtrate from the ground tissue was evaporated and the residue taken up in sea-water.

Of attempts to find the constituent of extracts of *Phallusia* or *Polyandrocarpa* responsible for their remarkable effectiveness in inducing normal metamorphosis, only brief mention may be made in this report. The filtrates from fat solvents showed a slight accelerating effect only and even this may possibly be accounted for on the assumption that such solvents as acetone and absolute alcohol so dehydrate the tissue that a sufficient quantity of water is present in the filtrate to contain some of the activating substance in solution. Such an explanation is supported by two results of experiments: first, filtrates from ether, chloroform or benzene have no accelerating effect; second, sea-water extracts of the residues of all of those fat solvents have the same accelerating potency as sea-water extracts. It is very doubtful, therefore, whether the activating substance is fatty in nature. Precipitating the proteins from distilled water extracts by the addition of either phosphomolybdic or sulphosalicylic acids and filtering out the protein did not decrease to any significant extent the accelerating effect of the original extract. The large proteins may thus be ruled out. Boiling the extracts for several hours; drying the tissue at 140° C. 48 hours, or evaporating the extract to dryness and taking up again in distilled water, caused only a slight decrease in their accelerating potency.

Heavy metal salts—Experiments with heavy metal salts, though considered only preliminary, have yielded results that are interesting because of the similarity of the results obtained to those with tissue extracts and for their possible significance in the search for the fundamental nature of reactions involved in metamorphosis. Of an extensive list of metallic salts, five have been shown to be effective in very dilute solutions in inducing metamorphosis: copper, iron, aluminum, nickel and zinc. The optimum concentrations for experiments reaching a conclusive result in a period of 2 hours have been: 2×10^{-6} molar for copper salts; 2×10^{-4} for iron, aluminum and nickel; 1×10^{-3} for zinc. A species difference was shown in the response to copper and nickel salts: *Polyandrocarpa* larvæ treated with copper salts of 2×10^{-6} molar metamorphosed in an extremely short time and the subsequent growth of the zooids was normal and rapid, but *Phal-*

lusia larvæ similarly treated failed to show growth of the zooid, although involution of the tail of the larva was greatly accelerated. In concentrations of 5×10^{-7} molar, however, metamorphosis of *Phallusia* larvæ was accelerated and was followed by normal growth. On the other hand, nickel salts were effective in the induction of normal metamorphosis in *Phallusia* larvæ, but showed no effect on *Polyandrocarpa* larvæ.

Swimming Movements of Fishes: Anatomy and Physiology of the Pectoral Fin, by John E. Harris

The pectoral region of a number of types was used for a detailed study of the anatomy and mechanism of the fin and its girdle. In accord with observations reported last year the fishes studied were classified into three groups, determined by the function of the pectoral fin in the living animal.

(a) Forms which employ the pectorals almost entirely for forward locomotion: *Pseudoscarus guacamaia*, *Sparisoma rubripinne*, *Pomacanthus aureus*, *Scorpena brasiliensis*.

(b) Forms using the pectorals for forward locomotion, but more usually for "backing" and "hovering"—maintenance of a stationary position: *Epinephelus morio*, *E. striatus*, *Mycteroperca bonaci*, *Promicrops itaiara*, *Lutjanus analis*, *Sphyræna barracuda*.

(c) Forms using the pectorals almost entirely as "brakes" and rarely, if ever, for forward locomotion: *Euthynnus alletteratus*, *Scomberomorus regalis*, *S. cavalla*, *Caranx crysos*, *Seriola dumerili*.

There is a very close correlation between these locomotor types and the anatomical structure of the pectoral region, even in the absence of close phylogenetic relationship. The proportionate sizes of the abductor, adductor and arrector musculature very accurately meet the requirements of the animal for locomotion—requirements which in their turn are fixed by the fish's mode of life.

The ratios of the sizes abductor/adductor muscles in the three groups above are 1.25, 0.82 and 0.54, respectively. Not only do the mechanical needs determine this ratio, but they similarly determine the relationships between the superficial and deep muscles on each side. It is possible in any fish to link together (a) the type of fin movement; (b) the size and shape of the pectoral girdle; (c) the attachment, size and direction of the separate fin muscles, and (d) the shape of the fin, so that any one of these factors uniquely determines the other three.

The mode of production of the various types of fin movement has never been studied in detail, and advantage was taken of availability and tractability of the material to make a number of experiments with the red grouper, *Epinephelus morio*. The articulation of the fin rays, and the leverage and direction of muscular pull were worked out, and hence the action of each muscle on the fin determined. These results were confirmed on a fin preparation dissected out from the pithed fish. The fin, the essential parts of the girdle, and the fin musculature and nerve supply can be completely isolated from the animal by quite a simple operation. The motor nerve paths having been determined by electrical stimulation, the effects of the stimuli on the fin were observed by placing the whole preparation in frog Ringer solution, or in sea-water diluted with twice its volume of distilled water. Even in the latter solution, excitability is maintained for two or

three hours. The fin being completely immersed in aqueous solution is subjected to the same fluid resistance as in the normal animal, and the movements obtained consequently reproduce accurately those which the living animal would perform under like stimuli.

The effects of individual muscles and combinations of muscles on the fin motion have been studied by observing the result of stimulation after section of the appropriate motor nerves, curarisation of the neuro-muscular junction and section in the muscle tendons themselves. The method (mentioned in last year's report) of recording fin movements graphically was further developed and applied to obtain a simultaneous record of the horizontal and vertical motions of a number of fin rays from different parts of the fin, thus providing a true picture of the motion of the fin as a whole.

The most significant result of the study has been to demonstrate the serialization of the motor nerves in the fin of *Epinephelus*. It is possible to distinguish three separate motor nerves, arising apparently from three successive segments of the spinal cord. The most anterior of these nerves stimulates the *arrector dorsalis* and *arrector ventralis* muscles, together with all the muscles of the next few (2 or 3) rays. The second of the three nerves causes contraction in all muscles (superficial and deep abductors and adductors) of the next five or six rays of the fin, and the most posterior nerve stimulates these muscles for the lowest rays, and also contracts the *adductor radialis*. The *coracoradialis* muscle, which has been incorrectly reported absent from the fin of *Epinephelus*, is actually a very small and thin sheet of muscle, which can not be of great importance, but whose nerve supply is also derived from this third nerve.

The investigator is at present preparing a series of experimental studies on the hydrodynamical characteristics of the fish body form. Particular attention is being paid to the stabilizing influence of the fins, and a certain amount of material has been accumulated for the purpose at Tortugas during this season.

Intracellular pH Determinations on Marine Ova, by M. J. Kopar

The micrurgical method of injecting sulphon phthalein indicators into living cells as developed by Dr. Robert Chambers has been extended to a study of the excellent and abundant material available at Tortugas. Aqueous solutions of various sulphon phthalein and other indicators were injected into living marine ova. The number of sulphon phthalein indicators used by Chambers was augmented to include the K and NH_4 salts. In many respects the K and NH_4 salts are more favorable than the commonly used Na salts. The indicators were used either alone or mixed with a balanced salt solution containing a ratio of K:Na:Ca of 36:4:1.

About 2000 microinjections were made on the immature oocytes, mature (unfertilized and fertilized) and cleaving ova of the following invertebrates: *Lytechinus variegatus*, *Triplonastes esculentus*, *Echinometra lucunter*, *Eucidaris tribuloides* and *Phallusia nigra*.

The cytoplasm of the mature ova of *Triplonastes* was blue to Brom cresol green, but yellow to Brom cresol purple, Brom thymol blue and Phenol red. The pH value is therefore between 5.4 and 6.0. A cytoplasmic acidity as high as this has not been previously reported.

The ova of *Lytechinus* were very favorable for micrurgical work. The ovum is large and very transparent. The following table gives the pH value as determined on the mature ova of *Lytechinus*.

INDICATOR	COLOR IN CYTOPLASM	INFERRED pH
Brom cresol green	Blue	> 5.4
Brom cresol purple	Violet	> 6.6
Brom phenol red	Red	> 6.6
Chloro phenol red	Red	> 6.6
Para nitro phenol	Yellow	6.8
Brom thymol blue	Green	6.8
Phenol red	Yellow	< 6.8
Meta nitro phenol	Colorless	< 7.2

The results of this investigation place the cytoplasmic pH of *Lytechinus* between 6.6 and 7.0; a value agreeing with the results obtained on other cells by other investigators.

A considerable difference in the reactivity between sea-urchin and ascidian ova to pH indicator solutions was found. A membrane surrounding the injected zone was produced in 95 per cent of the sea-urchin ova. No membrane was formed in the ascidian ova. The cytoplasm of *Phallusia* ova appeared to be completely miscible with the indicators used. All indicators diffused readily through the cytoplasm. Such complete diffusion rarely took place in sea-urchin ova. Occasionally phenol red diffused slowly into the cytoplasm through the newly formed membrane surrounding the injected zone. Other cases of diffusion took place only when a membrane was not formed.

Unfertilized ova of *Lytechinus* previously injected with indicator solutions were capable of forming a fertilization membrane following insemination. Actual fertilization was not observed and amphiaster stages were not formed.

The effects on division following the injection of pH indicators into fertilized ova of *Lytechinus* were very interesting. Indicators injected into any part of the cell prior to the formation of the amphiaster completely inhibited cleavage. During the amphiaster stage, cleavage was prevented if the indicators were injected into the astral or spindle zones. Injections into the cortex did not inhibit cleavage. Injections into the furrow zone only delayed cleavage at the point of injection.

Similar effects were observed in the cleaving ova of *Eucidaris* and *Echinometra*. Cleavage was never completed in *Phallusia* ova injected either before or during the amphiaster stage. Even though the indicator was injected directly into the cortex, diffusion into the astral and spindle zones immediately took place. This difference between sea-urchin and ascidian ova is apparently associated with internal membrane formation. In the sea-urchin ova the diffusion of indicators into the astral or spindle zones is prevented by the formation of a membrane around the injected solution.

Osteological notes and descriptions of new species of fishes, by
W. H. Longley

The summer's work was directed wholly to the project upon which report is made elsewhere in this volume. Incidentally in attempting to distinguish species, I note in *Alutera ventralis*, described below, a microscopic vestige of the reduced ventral girdle of *Monacanthus*, which makes it necessary to redefine the genus *Alutera* if it is to be maintained. It appears also that in Sparidæ it is the fused first and second interhæmal bones which are hollowed to receive the tip of the air-bladder, but in Gerridæ the first only. The application to the one family of a terminology fitting the other has gone long uncorrected. In the Acanthuridæ, finally, a mechanism may be observed for locking dorsal and anal spines in erect position, which is different in principle from that serving the same purpose in Balistidæ and Monacanthidæ.

Its development in the same form and to the same extent in connection with first dorsal and first anal spines seems no case of coincidence: the elements of the contrivance were apparently present in simpler form in the dorsal and ventral fin supports of less specialized ancestors.

As work proceeds, it appears that the following are species not heretofore recognized:

Saurida normani n. sp.

D. $11\frac{1}{2}$ - $12\frac{1}{2}$; A. $9\frac{1}{2}$ - $10\frac{1}{2}$; P. 13. The distance from dorsal origin to tip of upper jaw is less than that from dorsal origin to adipose fin and equal the distance from insertion of pectoral to anal origin. Depth 7.3, head 4.2, diameter of eye less than interorbital width, one-fifth greater than the length of the snout and 4.0 in the head. The lower jaw not projecting, not visible from above when mouth is closed.

Lateral line scales with pores 54 to base of caudal, in all 56. Between the middle of the dorsal fin and the lateral line $4\frac{1}{2}$ rows, about 17 scales before the dorsal origin. None to several teeth on vomer on either side just before anterior in outer palatine series.

Pigmentation slight, bluish spots along scale rows above lateral line; in some specimens a distinct series of dark spots along upper border of caudal fin.

Not rare south of Tortugas from 60 to 100 fathoms, where it attains the length of at least 375 mm. Differs from known Atlantic species by short lower jaw; from *S. suspicio* by long pectoral, from *S. caribbæa* by larger eye, fewer anal fin supports, fewer scales in lateral line; from *S. brasiliensis* and *S. parri* by smaller scales; has fewer pectoral fin rays than Indo-Pacific forms except *S. gracilis*, from which it differs in squamation.

Named in appreciation of Mr. J. R. Norman's contributions to ichthyology and to knowledge of *Synodontidae* in particular.

Serranus notospilus n. sp.

D. X, $12\frac{1}{2}$; A. III, $7\frac{1}{2}$; P. 15-16. Scales 6-47-15, three or four additional with pores on base of caudal; on the cheek in 6 oblique series, interopercle completely covered by scales. Gill-rakers 10 and 3 rudiments on lower limb of anterior arch, slight, the longest treble the interspace. Hermaphroditic; sexually mature at the length of 60 mm. Usually with an indistinct pattern of bars of which one crosses the soft dorsal fin, the portion upon which is so much darker than the remainder as to suggest the specific name. In the type, at total length 86 mm., the eye enters 2.75 times into head, which equals depth and is contained 3.1 times in the standard length.

Common in 40 to 60 fms. in the type locality, south of Tortugas. The few rows of scales on cheek distinguish this from West Atlantic species except *S. tortugarum* below, *S. fuscus* and *S. atrobranchus*. From *fuscus*, which has 18, it is distinguished by its fewer pectoral rays, from *atrobranchus* by larger eye, color and squamation.

Serranus tortugarum n. sp.

D. X, $11\frac{1}{2}$ - $12\frac{1}{2}$; A. III, $7\frac{1}{2}$; P. 14. To base of caudal fin lateral line scales with pores 50; scales on cheek in about 7 oblique series, none cycloid; interopercle scaleless. Gill-rakers on lower limb of anterior arch 19 to 21. Color rufous orange above, becoming paler on sides and broken between the interorbital space and base of caudal by 9 narrow vertical lines of blue, of which the greater number do not cross the lateral line.

Taken at the depth of 30 fathoms, south of Tortugas. Hermaphroditic, sexually mature at the total length of 80 mm., or little more. Distinguished from West Atlantic species, except *S. tabacaria*, by the serrate sub- and interopercle; distinguished from *S. tabacaria* by color pattern, larger scales—especially noticeable on cheek—and larger number of gill-rakers.

Pronotogrammus aureorubens n. sp.

D. X, 15 $\frac{1}{2}$; A. III, 8 $\frac{1}{2}$; P. 16-17. Scales 6 to 44 to 46 to 17, ctenoid; none in anterior half of interorbital space, on snout or maxillary. Gill-rakers long, slender, closely approximated, 28-29 on lower limb of anterior arch. Sexes separate. In the type at total length 275 mm., the ocular diameter enters three times into the length of the head, which equals the depth and enters three times into the standard length.

Rather common south of Tortugas, the type locality, at depths of 100 to 200 fathoms. Nearest to *P. eos* Gilbert, from which it differs in having smaller scales, more oblique mouth and feebler dentition.

Eucinostomus poeyi n. sp.

Known from Texas, Cuba and Haiti to Panama, Curacao and Trinidad; source of persistent confusion regarding specific limits within the genus; in dentition, squamation—except as indicated below—and in fin formulæ entirely representative. From described species, except the African *E. octactis* (Blkr.), of which *E. melanopterus* (Blkr.) is a synonym, it is distinguished by having 8 gill-rakers instead of the usual 7, scores of specimens being involved in the counts. From all but *E. octactis* and *E. californiensis* it differs by having a subterminal bar of positive white, not a mere pigment-free area, below the black dorsal tip; from *E. lefroyi* by having 3 anal spines; from *E. gula* by having the premaxillary groove open anteriorly, and straighter and stronger ridges formed by the second along the sides of the hollow first interhæmal, with which it is united. In depth it markedly exceeds *E. argenteus* B. & G., of which *E. pseudogula* Poey is a synonym, and from *E. octactis* it is distinguished by its greater depth, shorter head and the persistence of the contrastive black and white of its dorsal fin in adult life.

The type. No. 22014 MCZ (orig. No. 189), collected by Poey in Cuba, is about 240 mm. long, 186 mm. in length to the base of the caudal; depth 71 mm., head 60 mm., eye 16 mm., 2d dorsal spine 30 mm. long.

Triacanthodes lineatus n. sp.

D. VI, 16; A. 14; P. 13; V. 1, 2. The dorsal spines graduated downward, the first almost as long as the head, the last equal the horizontal diameter of the pupil. Ventral spines strong, extending to tip of pelvic bone, the second ray minute, adnate to the body wall. Teeth in each jaw strong, conical, in a single series except anteriorly where there is a single pair in each within the main tooth-row. The opercular cleft not extending ventrally quite to middle of pectoral base. Body covered with small scales, with a single or several spinules, these extending upon the fluted dorsal and ventral spines to their tips. Rather rosy dorsally in life, vertical fins faintly orange, body marked with about eight longitudinal linear non-anastomosing streaks of green.

Occurs between 60 and 125 fathoms, south of Tortugas. Sexually mature at 100 mm. and attains at least the length of 120 mm. Total length of type 73 mm., length to base of caudal 57 mm., depth 40 mm., head 22 mm., eye 7.0 mm.

Alutera ventralis n. sp.

Dorsal rays 37 to 40; anal rays 39 to 42. At the total length of 50 mm. depth between dorsal and anal origins enters 3.4 times, and at the length of 140 mm. 2.5 times into the length to base of the caudal fin. Most closely resembles *Alutera schoepfi* (Walbaum), with the young of which its young occur in floating Sargassum at Tortugas. From that species it is distinguished by having fewer and stronger barbs on the first dorsal spine and the spine itself shorter, stouter, regularly shapen to the tip, not thin and spindling, scarcely the same in two individuals. Its dorsal rays are upon the average four, its anal three more than the average in *A. schoepfi*, and throughout its known size range it is considerably the deeper of the two. Its distinctive ventral girdle is mentioned above.

The type is a specimen 120. mm. long, to base of caudal 78 mm., depth between dorsal and anal origins 34 mm., dorsal rays 39, anal 42. With the other types, except that of *Eucinostomus poeyi*, it is deposited in the U. S. National Museum.

Effects of Temperature and Light upon the Inherent Potential of Valonia,
by Gordon Marsh

The change with temperature in the inherent potential across the protoplasmic layer of *Valonia ventricosa* was studied over the interval from 6° to 36°C. Cells were impaled on glass capillaries filled with artificial sap (formula of Osterhout) and immersed in beakers of sea-water. Ag:AgCl electrodes were employed and the E.M.F. measured with a potentiometer having a sensitivity of approximately 0.2 millivolts. The temperature was controlled by hand, usually to within 1°C., by adding ice or heated sea-water to a vessel containing the beakers. The temperature was recorded within the beaker at the level of the cell with a thermometer reading to 0.1°C. The Q_{10} 's calculated from the data are as follows (numerical averages):

6.4-19°C.	4.16
16.4-30°C.	1.83
26-36°C.	1.57

The potentials showed considerable variation and lag during the process of adjustment to new temperatures. The upper limit of toleration of temperature, as tested by survival of intact cells, appears to lie immediately below 40°C.

The effect of illumination upon the magnitude of the P.D. was also investigated, although the results are not complete. The light source used was the north sky; the cells were placed upon a table before the window. No measure of the absolute intensity of illumination was made. Relative intensity was controlled by altering the aperture of a light-tight box. Measurements were made at room temperature, which changed slowly. The resultant effect upon the potential could not be confused with the very rapid response to changes in light intensity.

Complete shrouding from light produced a decrease in potential for different cells of from 20 to 90 per cent of the level in light. The time course of potential change consisted of an immediate drop followed by several characteristic waves. These appeared consistently from cell to cell and evidently reflect some very definite internal process. Reexposure to light restored the potentials approximately to their original magnitudes. The per cent depression upon shrouding was a function of the original light intensity and, possibly, of the "physiological state" of the cell. Between full light and complete

darkness the potential varied with light intensity, but the data at hand is insufficient to determine the precise relation.

By the use of Wratten color filters (kindly loaned by Dr. W. L. Doyle) the effective wave-length was tentatively determined to lie between 4000 and 5000 Ångström units, probably in the blue region of the spectrum. The red and ultra-violet regions and the band from 5000 to 6000 Å. showed no effect upon the potential. This is correlated with conditions in the normal habitat of *Valonia* where, even at shallow depths, illumination consists principally of blue light reflected from the sea-water and surroundings. These observations are of interest since they suggest a direct linkage of the E.M.F. with photosynthesis.

The magnitudes of the Q_{10} and the effect of light are incompatible with any theory of the origin of the inherent P.D. of *Valonia* based simply upon the difference in concentration of potassium or other ions between the sap and sea-water. They are, it may be emphasized, in harmony with Lund's theory that the electromotive force is an oxidation-reduction potential arising from and maintained by the normal respiratory processes of the cell.

Regeneration in the Enteropneustan Ptychodera and the Annelid Euratella,
by R. G. Stone

Ptychoderæ used were kept unfed in dishes of running sea-water during the experiments. Under such conditions they live about 35 days in the laboratory.

Replacement of severed anterior regions occurs readily. The proboscis is replaced in approximately 14, proboscis and collar in about 18 days, and proboscis, collar and most of the branchial region in 24 to 26 days. In all instances structures replaced attain normal length while still slender. They do not reach normal diameter during the period they remain alive in the laboratory.

Anterior regeneration does not occur when the animal is severed behind the branchial region, and non-regenerating posterior ends so obtained live only a few days. Posterior regeneration was observed infrequently. It occurs at the junction of the branchial and hepatic regions.

Anterior ends extending beyond that point are usually divided within a few days by constriction adjacent to it. The wound heals and in a few instances a small amount of new tissue is formed. From the same region then where the greatest anterior replacement occurs, after replacement of proboscis, collar and branchiæ, posterior replacement appears very limited. This experience accords with the facts that when collected, specimens were frequently regenerating anteriorly from various levels, though none was ever found replacing posterior regions.

Material has been fixed for histological examination at all stages in regeneration.

The sabellid *Euratella* regenerates anteriorly, and branchiæ, tentacles and head segments are replaced at approximately the same rate at any level excepting a small region at the posterior end. In continued investigation of effects of radium radiation on annelid regeneration use was made of 125 mg. of radium loaned by the National Research Council. Little change was observed in anterior regeneration after exposures up to 20 hours. With longer radiation, however, there was a rapid decrease in both rate and amount, and after 40 hours exposure replacement was inhibited. Radiated worms were severed at different periods up to 45 days after exposure, but none regenerated.

A complete series of radiated and normally regenerating worms has been fixed for histological examination.

Investigations on the Photodynamic Properties of Vital Dyes,
by D. H. Tennent

During these investigations a detailed study of the photodynamic effect of Auramine O, Brilliant Cresyl Blue and Neutral Red on the eggs of the sea-urchin *Lytechinus variegatus* was made.

The striking characteristic of these dyes is that concentrations that are non-toxic in diffuse light or in darkness become exceedingly toxic in sunlight.

The eggs were inseminated, then, at stated intervals, transferred to solutions in sea-water of the dye being tested and exposed to sunlight for selected lengths of time.

The problems that presented themselves concerned effective concentration of dyes, length of exposure to sunlight necessary to produce toxic effects, time after insemination that the egg became most sensitive to the action of the dye, nature of the result produced, and mechanism of the action.

Auramine O in concentrations of 1:300000 and 1:600000 was toxic both in the diffuse light and the sun-treated cultures; in concentrations of 1:1200000 the eggs of the diffuse light cultures developed abnormally, while those of the sun-treated cultures failed to develop; in concentrations of 1:2400000 development of eggs in the diffuse light cultures approached the normal, while in the sunned cultures division of the nucleus was not accompanied by division of the cytosome. In concentrations of 1:4800000 the development of the diffuse light cultures was approximately normal, but was highly modified in those that were sun-treated.

In Brilliant Cresyl Blue solutions of the concentration 1:20000 eggs were cytolyzed if exposed to sunlight. Concentrations of 1:40000 and 1:80000 were effective to a lesser degree under similar circumstances.

Neutral Red in concentration of 1:150000 was non-toxic in diffuse light cultures and in cultures exposed to sunlight for three minutes or less. It was increasingly toxic to cultures sunned for from 3 to 8 minutes, and generally fatal to any normal development if exposed to sunlight for longer than 8 minutes.

The effective light in the production of the photo-dynamic effect of neutral red was found to lie in the short waves of the visible spectrum. Cultures protected by a Wratten A, No. 25 (Red) filter were protected perfectly, the eggs developing well, while those that were screened from ultra-violet light were killed by an exposure of 20 minutes to sunlight.

Auramine O, in toxic concentrations, checked development instantly. If the eggs were introduced to such solutions during the process of fertilization the germ nuclei failed to unite.

Brilliant Cresyl Blue, under the action of sunlight, slowed development and in concentration of 1:20000 produced cytotoxicity.

Eggs with intact nuclei when sunned in solutions of neutral red underwent blister cytotoxicity, the surface of the egg forming a mass of colorless blisters while the center remained as a red core containing the nucleus. If placed in the neutral red solutions and sunned after the nucleus had broken down and the mitotic spindle formed, the eggs completed this division but later development was abnormal.

Both brilliant cresyl blue and neutral red appear as stained granules or globules in the egg. The task of determining whether both stain the same bodies is made difficult by the fact that both are red in transmitted light after staining with dilute solutions of the dyes. By careful observation of double stained eggs, and staining with brilliant cresyl blue until the granules became

blue it was possible to determine that the same inclusions are stained by both dyes. In eggs so treated the blue granules, after staining with neutral red, show a red center and a blue rim.

The mechanism of the photodynamic action may possibly be determined from material that has been preserved for cytological study.

Experiments were also performed with Methylene Blue, Fluorescein and Eosin Y.

Other experiments with *Lytechinus* eggs involving the use of KMnO_4 , AlCl_3 , $\text{Cu}(\text{NO}_3)_2$, $\text{Ni}(\text{NO}_3)_2$, Glutathione, Cysteine, Cystine, and Di-iodo-tyrosine were also performed. The results of these can not be stated until after the cytological examination of the material

GEOPHYSICAL LABORATORY ¹

ARTHUR L. DAY, DIRECTOR

The help which physics and chemistry can give to the study of rocks and the processes of their formation is necessarily limited by the fact that only the thinnest layers of these rocks forming the exposed surface of the earth are accessible. Underlying materials from which the present surface rocks were doubtless formed and in which similar formation processes may now be going on are quite out of our reach below a depth of approximately one mile. Below that point in most regions, even if we were able to provide an opening, temperatures would be too high for human approach. In these circumstances the geologist naturally turns to the volcanoes through which samples of deep-seated material are brought to the surface, often in fluid or gaseous condition, from which much may be learned.

The study of volcanoes may be approached in three of their phases, though not equally well in all. The violent phase of volcanism in which explosive activity and lava outpourings commonly occur is inaccessible to near approach and moreover is often of such short duration that successful studies with competent equipment are rarely possible. There are types of volcanoes, like Kilauea in the decade immediately preceding 1924 during most of which time a lava lake some 500 feet in diameter maintained a more or less constant activity, in which fluid lava may be successfully approached. Taking advantage of this opportunity, students from the Geophysical Laboratory actually succeeded in collecting gases directly from the molten lava without contamination by atmospheric air. Out of this investigation it became clear for the first time that the behavior of lava during eruption was largely dominated by its gas content and that gaseous ingredients were a normal and regular part of its composition, notwithstanding the fact that the older rocks bear but inadequate evidence today either of the total amount or of the original proportions of the gases which must have participated in their formation. In 1924 the quantity and activity of the gases at Kilauea became such as to blow out the entire crater and its setting, enlarging the opening to something like a ten-fold volume and lowering the bottom out of reach of human approach. Thus ended the opportunity for intimate study of an active lava crater for the time being.

During the past year the effort has been made to continue these studies in Central America where several volcanoes are more or less continuously active, but the violence of their behavior is such as seriously to limit the possibilities of physical and chemical study. Nevertheless, collections have been made in this region and some measurements which will be reported upon after opportunity has been given for their study.

Still a third attempt has been in progress during the past three years at the well-known crater of Mt. Pelée in Martinique. It will be recalled that in 1902 this volcano broke out in active eruption with initial explosions of such violence and direction as to effect the complete destruction of the city

¹ Situated in Washington, District of Columbia.

of St. Pierre and of all its thirty thousand inhabitants except two. Something over three years ago signs of renewed activity developed in which most of the explosive phenomena of the earlier violent phase were repeated upon a somewhat milder scale which rendered them approachable with some degree of success. Mr. Perret's volume entitled *The Eruption of Mt. Pelée, 1929-1932* containing the results of painstaking and continuous observation during this period with modern equipment and his unique experience, is now in press and will appear during the present calendar year.¹

Such are the occasional opportunities which have been afforded to us to study crust-forming rock materials at the time of their ejection in fluid condition.

A second phase of volcanism of equal importance in its geological significance, though a step farther removed from ultimate causes, is represented by that state of waning activity when fumaroles and hot springs appear in volcano regions. Many valued ore deposits are commonly thought to have their origin in depositions from currents of hot gases (fumaroles) or from circulating hot waters. While such emanations are always approachable and often convenient for human study, they have heretofore usually been approached upon a basis of economic usefulness rather than of causal significance.

The third phase of volcano study is concerned with the volcano edifice as a recent formation after all activity has ceased. This problem does not fall within the domain of our present studies.

To return to the fumaroles and hot springs, which offer the advantage of continuous accessibility, these have formed a definite and principal part of the program of the Geophysical Laboratory since 1914. Three comprehensive surveys and a considerable number of individual papers covering work among the hot springs of Lassen National Park,² in the "Valley of Ten Thousand Smokes" (Mount Katmai, Alaska)³ and at "The Geysers" in Sonoma County, California,⁴ have already been published. This part of our program has perhaps reached its most elaborate development in this calendar year with the publication of the large volume entitled *Hot Springs of Yellowstone National Park*⁵ and its near relative *Bore-hole Investigations in Yellowstone Park*.⁶ Together these Yellowstone publications cover a continuous study, over a period of some seven years, of the one region in the world containing the most diversified examples of hot-spring activity thus far discovered. In Yellowstone Park many hundreds of hot springs of widely variable type and more than a hundred geysers have been studied with great care to determine their physical and chemical behavior, the sources of their heat energy, their relation to rainfall and drainage, their mineral content, and their solvent effect upon the rocks from which they emerge. Practically all the conclusions reached were established quantitatively, by measurement, pursued to the limit of accessibility of the relations studied.

¹ Carnegie Inst. Wash. Pub. No. 453.

² Carnegie Inst. Wash. Pub. No. 360.

³ Publications of the National Geographic Society, Technical Series, Nos. 1 and 4.

⁴ Carnegie Inst. Wash. Pub. No. 378.

⁵ Carnegie Inst. Wash. Pub. No. 466.

⁶ By C. N. Fenner. To be published presently.

We were particularly fortunate here as in "The Geysers" region in being able to make or to have access to bore-holes which penetrated as far as practicable into the subjacent region in which both the chemical and the physical activity developed, and so to determine with reasonable assurance the source of the heat, the source of the water, the manner of its circulation, and the alteration of the rocks through which it passed. It is perhaps fair to say, therefore, that a greater body of observed fact concerning such phenomena has here been gathered together than ever before and an opportunity given for more direct inference regarding causes and relationships than has been possible up to this time. The body of measured data is so large and the observed relationships so varied that any adequate review within the limited space of an annual report is scarcely possible.

The manner of approach to the problem and the significance of some of the observations made may be gathered from a few brief references. For example, it has been customary in the earlier literature on the subject to regard hot springs as differing but little from cold springs in their relation to drainage; perhaps only in the obvious fact that in the course of their passage through the drainage basin they must have come in contact with some source of heat. It was quite naturally inferred that this meant hot rocks along the way. Closer study, however, revealed the fact that the output of Old Faithful Geyser in its hourly discharge, day and night throughout the year, would require cooling to geyser temperatures a red-hot rock surface several square miles in area and a foot thick to supply the necessary heat for a single year and, furthermore, that this supply would require to be renewed each year by fresh exposure or otherwise. To make the matter worse, there are many other geysers of high discharge volume in the same basin with Old Faithful and many hot springs besides. Obviously these magnitudes present a situation practically impossible of realization through the agency of simple contact with hot rocks. To account for such a heat supply, only the continuous exhalation of hot gases from a considerable body of uncrystallized magma below ground seems to offer adequate possibilities. To clinch this conviction we bear in mind that magmatic gases now found in the rocks, and on certain occasions, above referred to, actually collected from fluid magma, contain above 90 per cent of steam of high specific and latent heat which must originally have been superheated. Here is a source of energy entirely adequate to heat circulating surface water and available for hundreds or thousands of years, about which there can be no considerable mystery.

It is also observed that the springs carry certain elements like arsenic and boron which are not found in comparable quantities in the surface rocks through which the waters circulate and therefore could not be derived from that source, but which are usually present in the volatile constituents of the magma. The case for an adequate heat supply appears, therefore, to have been established. Dry hot rocks could not supply heat continuously in sufficient quantity, nor could they supply boron or arsenic. The magma supplies both in its emanations. A very rough estimate of the amount of heat so supplied to the waters of the Park, disregarding all losses such as evaporation which are not measurable, would be represented by the continuous melting of about 3 tons of ice per second.

Detailed studies have also determined that the hot areas of Yellowstone Park are divided into three more or less characteristic groups; the alkaline springs (which include the geysers) characterized by large volumes of water, abundant heat supply, relatively deep-seated circulation and sinter deposits; the acid or sulphate areas, usually found on hillsides or regions of limited water supply, characterized by shallow water circulation, rock decomposition by sulphuric acid, and sulphate deposits with little or no sinter; and the bicarbonate group of which Mammoth Springs is the chief representative, characterized by abundant water supply and reaction of excess carbonic acid upon limestone to produce calcium bicarbonate below ground with eventual deposition of the carbonate when the carbon dioxide is released at the surface. It may fairly be concluded that the last group would become practically identical with the first group in regions where no limestone was present.

These magmatic gases ranging upward from the magma and dissolving in the waters that circulate through the surface lavas and accumulated valley gravels leach the rocks at contact, removing the glass and feldspars in whole or in part, replacing sodium with potassium in certain areas and carrying away in the discharged waters an enormous quantity of dissolved or suspended mineral matter. The total amount of this dissolved mineral matter as measured in the springs and discharge channels of Yellowstone Park is something like 390 tons in each 24 hours.

The mechanism of the geysers found in the Park is much more complicated than was at first supposed. Bunsen's theory which was developed from observations on the Grand Geyser in Iceland about the middle of the last century and which has been generally acceptable to geologists since that time, does not properly account for the Yellowstone geysers. Indeed most of the geysers known to us would quickly revert to continuous steam fumaroles if no other explanation than that supplied by Bunsen and his collaborator Descloizeaux were available. That much further elaboration is necessary arises from the fact that the Yellowstone geysers generally, unlike the Grand Geyser of Iceland, do not return their discharged water down the geyser tube, nor, with the exception of Old Faithful, are they characterized by any regularity in the time interval between eruptions. A chapter in the present volume is devoted to a discussion of the observations in Yellowstone Park relating to these popular features, but no uniform and adequately comprehensive explanation has been found to cover all geysers. The details must be sought in the original publication.

In this volume comparison has been made of our results with those obtained by other observers in this and other hot-spring regions of the world. It has even been thought desirable to make an independent investigation of the hot springs of Iceland where the absence of trees and covering vegetation permits a clearer appraisal of the relation of the springs both to the surface drainage and to the lavas in which they originate. There is also in Iceland a longer recorded history (more than 1000 years) of the continuing behavior of conspicuous hot springs than is available elsewhere in the world. It is significant, too, that surface manifestations of active volcanism still continue in Iceland, while in most other hot-spring regions of the world hot-spring activity is related to volcanic activity now long dormant or extinct.

Preliminary observations in Iceland in 1934 have indicated the following conclusions¹ which may be compared with the Yellowstone studies.

"The alkaline springs are most plentiful in areas possessing a superior water supply. The acid springs, however, seem to be independent of the surface topography, but are clearly intimately associated with recent volcanic activity.

"All Icelandic springs are strongly influenced by earthquakes and volcanic eruptions. During an earthquake some of the existing springs disappear and new ones spring up. The lifetime of the individual springs may therefore differ considerably. Several of the voluminous hot springs are at least 1000 years old, but several examples are also known of springs which came into existence and disappeared in less than one year. . . . There are data on record showing that the temperature of the springs changes with time; some springs suddenly become hot and then cool off very quickly; others seem to be subject to slow fluctuations, but whether or not such fluctuations are cyclic is not known; still others have had the same temperature for centuries.

"Detailed mapping of a typical hot-spring area in southwestern Iceland as well as a study of data recorded from other hot-spring areas in Iceland clearly show the selective mode of occurrence of the various springs. It is not true that alkaline springs, particularly the geysers, are associated with liparite as Bunsen thought. However, they do show a pronounced preference for the 'Palagonite Formation.' The reason for this and other quite definite relations between certain types of springs and certain types of adjacent rocks are some of the interesting features that are now being studied."

The Yellowstone volume contains more than 100 tables of measured data and something over 200 illustrations.

IRON OXIDES

In its work of obtaining fundamental data necessary to an understanding of earth processes and earth history, one of the principal endeavors of the Geophysical Laboratory, from the time of its inception to the present, has been to carry out investigations that would help in the solution of the problems of the petrology of igneous rocks. With this end in view the study of the equilibrium relationships at high temperatures, in systems composed of the rock-forming minerals or of their component oxides, was initiated in 1904 and since then has been steadily extended.

In the gradual advance of these studies but little work was done at first on systems involving the oxides of iron. This was not because of any lack of interest for petrology, but rather because the difficulties in the way of satisfactory equilibrium studies were greater with these than with the other important rock-forming oxides. It is indeed only within the past few years that any extensive study of such systems has been made (See Annual Report for 1931-32).

One of the fundamental systems is Fe_2O_3 — FeO — SiO_2 . As yet no attempt has been made to work out this system as a whole, yet gradually information about it is being accumulated. The first work was an investigation of the system, Fe_2O_3 — Fe_3O_4 , by measuring the oxygen pressure at 1200° and at

¹ Tom. F. W. Barth.

1100° (Reviewed in Year Book No. 15, p. 146, 1916). Next it was found that some mixtures of iron oxide and silica, when melted, form two liquids. The subsequent determination of the compositions of such mixtures and of the temperatures at which they melt over a considerable composition range filled in a part of the ternary diagram (Reviewed in Year Book No. 27, p. 81, 1927-8). Next the ternary system, $\text{FeO}-\text{SiO}_2$, was extended from the compositions involving two liquids as far as FeO (Reviewed in Year Book No. 31, p. 85, 1931-32). The work on the oxides $\text{Fe}_2\text{O}_3-\text{Fe}_3\text{O}_4$, an abstract of which appears elsewhere in this report, is the latest contribution. Some side lights have been thrown on the system, $\text{Fe}_2\text{O}_3-\text{FeO}-\text{SiO}_2$, at high temperatures by other investigations here, and considerable work has been done elsewhere, but the studies mentioned above constitute the systematic high-temperature investigations within this system that have been carried out at this Laboratory.

With the exception of the first-mentioned vapor pressure work, all these investigations have been carried out by holding small charges of the material at a constant temperature for a sufficient time to insure a close approach to equilibrium, cooling them in such a way as to prevent, so far as possible, any change, then examining the material to determine its condition before being cooled. Although this is the essence of the method, the technique varies greatly from one part of the system to another. These oxides and silicate melts containing them not merely change in composition as the oxygen pressure is changed but react with the materials that may be used for containers. The working out of a part of such a system, therefore, involves much testing of methods and is laborious. It will be seen, for example, from the summary of the paper on equilibrium relationships of Fe_3O_4 , Fe_2O_3 , and oxygen, that this investigation, which consisted of a revision of a part of the earlier work on the same system and an extension of the work to higher temperatures, involved incidental investigations on a considerable number of subjects.

Although the labor will be many times greater than in similar studies on oxides that do not react with platinum or with the atmosphere, it now appears feasible to obtain a fairly satisfactory outline of the equilibrium relationships in the fundamental system, $\text{Fe}_2\text{O}_3-\text{FeO}-\text{SiO}_2$.

VOLATILE CONSTITUENTS OF ROCKS: FLUORINE¹

In order to formulate useful hypotheses with regard to the chemical transformations within the earth's crust, we need to know the chemical composition of the rocks and the reactions possible between the various mineral constituents at various temperatures and pressures. We also recognize the fact that the volatile constituents of the magma must be known and their effects studied so far as may be possible.

For many years we have nibbled at this last question in various ways. One was by collecting and analyzing the gases which were obtained directly from volcanic vents. Further information was obtained by melting the rocks or lavas in vacuo and determining what volatile materials still remained in them. As was to be expected, the major constituent proved to be water, which makes up between 80 and 99 per cent of the total gas

¹E. S. Shepherd.

content. Next in order were nitrogen and carbon dioxide with hydrogen and carbon monoxide much less in quantity and in such proportions as the conditions of the experiment might establish. In lavas, at least, the hydrocarbons are either lacking or present in insignificant amounts.

Next in importance to water, the most significant group and most reactive is that of the acid-forming elements, sulfur and the halogens. Sulfur and chlorine are of course readily determined, but the more reactive and elusive element fluorine usually has not been determinable. Yet our practical experience with slags, glasses and mineralized geological formations implies that fluorine is of great importance in reducing viscosity and in accelerating such reactions as we observe to have occurred between masses of igneous and other rocks.

With the publication of Willard and Winter's admirable method for fluorine, this limitation was removed and we started the long series of analyses from which we may hope to establish the significance of this element in geochemistry. We have as yet insufficient data to formulate general rules, but some of the indications obtained may be of interest.

The first fact that appears is that the amount of fluorine in rocks is several times larger than had been supposed. In a general way it has been assumed that the fluorine content would probably be about half that of the chlorine and amount at most to a few hundredths of one per cent, possibly only a few thousandths.

It was expected that obsidians would show larger amounts than most rocks, with granite following, and the more basic rocks least. This proves to be only partly true. An obsidian which Bowen collected at Lake Naivasha, Africa, contained 0.68 per cent fluorine and other glasses from the same general region show regularly one or more tenths of one per cent. The glassy top of a flow at the entrance to Njorowa Gorge shows 0.41 per cent while the crystallized interior of the flow (commendite) drops to 0.28 per cent. These values seem to be typical of lavas of the Eastern or Great Rift. Lavas of the Western Rift are also high in fluorine. The glassy selvage of a leucite nophelenite from two miles north of Kibati, Belgian Congo, shows 0.20 per cent as against 0.16 per cent for the crystallized material. This apparent escape of fluorine during crystallization finds a parallel in the Coso Mountains and in the Yellowstone Park obsidian where a completely enclosed spherulite yielded less than the black glass in which it was formed. It will require many more cases to establish this relation as a rule, but the observed facts are suggestive.

While the obsidians thus far have tended to run higher in fluorine, appreciably higher than the few granites examined, this is not always true. The obsidians from Little Glass Mountain in California show only 0.05 per cent for dense glass and drop to 0.03 in fully developed pumice. Newberry volcano (Oregon) shows 0.06 per cent and an obsidian from Lipari 0.09 per cent.

The two granites, Stone Mountain and North Jay, yield 0.04 per cent and the Marvine laccolite (Henry Mountains) 0.06 per cent.

Among the basic rocks the Granton diabase yields less than 0.001 per cent. Shonkinite and syenite from Skonkin Sag show a fluorine content of

0.20 per cent and a piece of shale included within the mass gives 0.22 per cent. An ancient altered lava from Iceland which we owe to Dr. Hawkes shows 0.34 per cent of fluorine and a more recent selvage 0.15 per cent.

The Italian volcanoes generally show a higher content of fluorine than those of North America. Thus, Aetna, 1910 flow, 0.06 per cent; 1669 flow, 0.03 per cent, and an ejected block from Stromboli (1912) shows 0.04 per cent. These figures are high for volcanoes, though Mt. Erebus, Antarctica, yielded 0.06 per cent. Lava from Lassen Peak yields only one or two hundredths of one per cent. Mt. Pelée, Martinique, never rises above 0.01 per cent even for the thoroughly fumed spine of 1902. Mauna Loa yields less than 0.01 per cent, whether the lava was collected at the summit crater or from flows much lower on the flank.

A Katmai rhyolite which apparently had evolved or transmitted large quantities of fluorine had retained only 0.02 per cent.

In spite of the insufficiency of the data at hand some interesting trends are indicated. Fluorine distribution may be regional, as in Africa, Italy and Iceland. This will be interesting if true. The Katmai instance as well as the Little Glass Mountain series and some reaction areas observed by Fenner imply that fluorine may very well have been present during the reaction period and then been dissipated; similarly the Njorowa Gorge material. It follows that fluorine evolution from active volcanoes may be greater than our records imply.

On the other hand it may well be true that fluorine tends to concentrate or settle down in suitable areas and is set in motion and reaction again by such rise in temperatures as the country rock experiences during igneous intrusion. Since the last phase of a volcano is marked by the predominance of sulfuric acid, the absence of fluorine around old volcanoes is not surprising. It seems probable that the absence of fluorine in any altered area need not imply that it was never present nor that it was not once a prime factor in the remains which we examine.

In passing we note that one sample of mud from the bottom, far out in the south Pacific Ocean, gave 0.11 per cent fluorine, which is surprising since recent studies indicate that rivers drop their fluorine where they mix with the sea-water.

Many hundreds more analyses will be needed before we can speak of the distribution of fluorine over the earth. Meanwhile such facts as we have seem worth recording. The work will continue.

PUBLICATIONS

- (861) The agency of algæ in the deposition of travertine and silica from thermal waters. E. T. Allen. *Am. J. Sci.* 28, 373-389. 1934.

Conceding the results of biological investigation, the writer recognizes these photosynthetic organisms as a factor in the deposition of travertine. Working in harmony with chemical principles, algæ favor the precipitation of calcium carbonate by the abstraction of carbon dioxide from its solutions. *Geologically* this factor is unimportant, at least in the Yellowstone Park. A number of reasons presented in detail make the case very clear. In the more active parts of the geyser basins the hotter waters are practically sterile, micro-organisms are scanty or absent, and several inorganic

agencies adequately account for the deposition of silica. On the other hand, where the tepid effluents of these heated waters collect in shallow pools, algal colonies, either by the absorption of water (van Neil) or by promotion of evaporation, greatly accelerate the precipitation of silica. Sheets of silica in lakes and silica bars across streams are formed from thermal waters *highly diluted and cooled*. That these formations are controlled by algae is suspected, but evidence is lacking.

(862) Thermal leakage rates of Dewar bottles. Walter P. White. *Rev. Sci. Instr.* 5, 379. 1934.

Experimental evidence had been presented that the total quantity of heat leaking to or from a Dewar bottle was, within wide limits, independent of the amount of water contained in it. Since a large fraction of the heat goes by way of the mouth, and the path for this heat is much longer when the water-level is low inside, it seemed that the above result must be erroneous. To test it, pint bottles of ice-water, completely immersed in a thermostat, were observed as they warmed for several days. When one bottle was only half full the total heat flow was about 0.7 as great. With pint bottles of extra quality filled to within 3 cm. of the mouth, which was quite open, the change of temperature per minute was about 0.0005 of the thermal head, varying somewhat with temperature and with thermal head.

(863) A note on the elastic properties of rocks. Roy W. Goranson. *J. Wash. Acad. Sci.* 24, 419-428. 1934.

A comparison of the elastic properties of material at depth evaluated from seismologic data with the known properties of rocks determined from laboratory measurements yields important information concerning the nature of the material and so constitutes an important resource in geophysics. However, in order to make such correlations, assumptions are made concerning the application of the elastic theory, the representative character of the specimens, the independence of the method employed, and the validity of extrapolated values. Large discrepancies among recent low-pressure data obtained by different methods led the author to examine the validity of these assumptions. It was deduced that for low-pressure data on rocks, none of them will be satisfied. It is suggested that the errors introduced as a result of the first two assumptions might be lessened considerably if the *sealed* specimen were given a preliminary seasoning at a high hydrostatic pressure. It was deduced that an *observational* discrimination exists in reading seismologic records resulting in calculated elastic properties of a higher order than those obtainable from low-pressure static measurements. A better comparison with seismic data will therefore be obtained by extrapolating (backwards) high-pressure static data.

(864) Hot springs of the Yellowstone National Park. E. T. Allen and Arthur L. Day. *Proc. Fifth Pacific Science Congress* 3, 2275-2283. 1934.

A brief statement of the results of an investigation which in extended form appears as Carnegie Inst. Wash. Pub. No. 466 (see No. 889 of this Report).

(865) The crystal structure of calaverite. G. Tunell and C. J. Ksanda. *J. Wash. Acad. Sci.* 25, 32-33. 1935. (Preliminary report.)

Crystals of calaverite from Cripple Creek, Colorado, were studied by means of the Weissenberg X-ray goniometer and the two-circle reflection goniometer. The dimensions of the monoclinic unit cell, all determined by purely röntgenographic measurements, are: $a_0 = 7.18 \text{ \AA}$, $b_0 = 4.40$

$c_0 = 5.07 \text{ \AA}$, all $\pm 0.03 \text{ \AA}$, $\beta = 90^\circ \pm 30'$. There are 2 "molecules" of AuTe_2 in the unit cell. The 2 atoms of gold occupy the positions, $0,0,0$; $\frac{1}{2}, \frac{1}{2}, 0$; the 4 atoms of tellurium occupy the positions, m, n, p ; \bar{m}, n, \bar{p} ; $m + \frac{1}{2}, n + \frac{1}{2}, p$; $\frac{1}{2} - m, n + \frac{1}{2}, \bar{p}$, where $m = 0.69$, $n = 0.00$, and $p = 0.29$, all ± 0.05 . The intensity calculations on which the atomic arrangement is based will be published in the near future.

(886) An experimental investigation of the effect of pressure on phase equilibria of sodium tungstate and of related thermodynamic properties. R. W. Goranson and F. C. Kracke. *J. Chem. Physics* 3, 87-92. 1935.

From the point of view of crystal physics, sodium tungstate is of interest in that it is trimorphous with the two inversion points separated by only 1° in temperature at atmospheric pressure, so that the intermediate modification has an exceedingly narrow range of stability. The high-temperature (I) form is stable from the melting point (695.5°) to 588.8° , the intermediate (II) form from 588.8° to 587.6° , and the low-temperature (III) form below 587.6° . The transition from the intermediate (II) to the low (III) form is generally delayed on cooling, hysteresis of 15° or more having been observed, depending upon the rate at which the temperature is changing. A study of the effect of pressure on the transition temperatures established that the three modifications can coexist at 588.8° under a pressure of 40 to 80 bars. Beyond this pressure, form III inverts to I at temperatures given by: $t = 588.8 + 0.025 (p - 40)$. At lower pressures, form III inverts to II at $t = 587.6 + 0.029 p$. The inversion II to I is unaffected by pressure, to within 0.5° . Although modification II ceases to be stable at the triple point (40 to 80 bars), the delay in the inversions is such that form I preferably inverts metastably to form II instead of directly to form III at pressures up to 613 bars. From measurements of the latent heats of the transitions, and the above data for the effect of pressure on the transition temperatures, it turns out that form II is produced from III with the relatively enormous increase of approximately 17 per cent in volume ($\Delta v = +0.035 \text{ cm}^3/\text{g}$), and with an absorption of 105 joules/g of energy. The inversion II to I is without effect on the volume; the energy change is also small, only 14 joules/g. Melting takes place with an absorption of 81 joules/g, and an increase in volume of $0.018 \text{ cm}^3/\text{g}$ or approximately 7.5 per cent.

(887) Geometrical and optical properties, and crystal structure of tenoite. G. Tunell, E. Posnjak and C. J. Ksanda. *Z. Krist.* 90, 120-142. 1935.

This is a final report on the problem a preliminary report of which was contained in paper No. 816 (see Annual Report of the Director of the Geophysical Laboratory for 1932-33, p. 72). In the final report it is proved not only that the structure described leads to correct values of the intensities of the X-ray diffraction effects but also that no other structure compatible with the usual application of the theory of space groups satisfies the conditions imposed by the observed diffraction effects.

(888) The surface features of the moon. F. E. Wright. *Sci. Monthly* 40, 101-115. 1935.

This paper presents a brief report of progress of the work of the Committee on Study of the Surface Features of the Moon. A short statement of the problems under attack is given together with a general description of the different methods which have been devised to obtain the necessary data of measurement for their solution. Before a critical study and analysis of the lunar surface features can be made, it is desirable that the geologist

know the nature of the materials exposed; also how they behave under the conditions which obtain at the moon's surface. In addition he should have a good lunar map, preferably a topographic map of at least the central portion of the moon's disk, as we see it. These requirements are not easy to meet. Determination of the nature of the surface materials is being accomplished by comparative measurements of the effects which lunar and terrestrial materials produce on sun's rays on reflection at different angles. These observations include measurements both of the amounts of plane polarization introduced by the reflection and of the percentages of light reflected at different parts of the spectrum (selective spectral reflection) which is transmitted by the atmosphere. Different types of receivers are used for this purpose: (a) the eye; (b) vacuum thermoelement; (c) photoelectric cell; (d) polarization ultraviolet spectrograph. The data of measurement thus far obtained indicate that the lunar surface materials are of the nature of light, non-opaque volcanic ashes and pumice. A photographic lunar map is in process of preparation which will be free from the personal equation present in existing lunar maps. Lunar photographs taken with the 100-inch telescope are transformed by photographing the image of the original photograph as viewed after projection on a globe. In this method the angular relations are preserved so that the projected image on the globe is, in effect, a miniature moon which can be photographed from any direction. The transformed pictures thus obtained represent the moon's surface projected on the plane of mean libration. The method proposed for preparing, by stereoscopic methods, a topographic map of the central portion of the lunar disk facing the earth is described briefly. At the present time the work of the committee is being concentrated on the measurements of the characteristics of the light reflected by the moon and by terrestrial materials under different angles between the incident and reflected beams of sunlight. It is expected that these measurements will be finished within the next three years.

(869) The system, MgO-FeO-SiO_2 . N. L. Bowen and J. F. Schairer. *Am. J. Sci.* 29, 151-217. 1935.

In view of the great importance of ferromagnesian silicates as rock-forming minerals, a study of equilibrium in the system, MgO-FeO-SiO_2 , has been carried out.

No ternary compounds are formed. The system is dominated by three series of solid solutions, the oxide series, MgO-FeO , which is complete, the orthosilicate or olivine series, $\text{Mg}_2\text{SiO}_4\text{-Fe}_2\text{SiO}_4$, likewise complete, and the metasilicate or pyroxene series, $\text{MgSiO}_3\text{-FeSiO}_3$, which is only partial, since FeSiO_3 does not exist as such, although solid solutions with nearly 90 per cent of that molecule are formed. The fields of these three mix-crystal series, together with the fields of silica as cristobalite and tridymite, occupy the whole liquidus surface of the triangle.

The broader temperature relations are comparatively simple. The magnesian end members of the solid solution series are invariably of higher melting temperature, with the result that the low liquidus temperatures all lie on the FeO-SiO_2 side of the triangle. More specifically, the oxide series is of Type I (Roozeboom); the olivine series, of the same type, has a melting temperature of 1890° at the Mg_2SiO_4 end, and of 1205° at the Fe_2SiO_4 end. The pyroxene series is much more complicated, by reason of the fact that at the magnesian end incongruent melting occurs, with separation of olivine, while at the other extreme, incongruent melting with separation of

silica prevails, and in connection with this latter phenomenon, the pyroxene field wedges out entirely at 1305° , below which temperature olivine and tridymite fields are in juxtaposition.

The relations of the metasilicates are further complicated by the fact that they form two mix-crystal series, the monoclinic stable at high temperatures, and the orthorhombic stable at low temperatures. The inversion temperature falls from 1140° at the pure magnesian end-member, to 955° at the iron-rich extreme. A section along the metasilicate join, even although it is not a binary diagram, brings out clearly these characters together with the variant incongruent melting mentioned above.

On account of the prevalence of solid solutions and of incongruent melting the courses of crystallization are of particular interest, especially in connection with the potentialities of fractional crystallization. These are discussed in detail, with application to natural magmas.

The simple character of the olivine diagram renders it possible to calculate, under certain assumptions, the latent heats of melting of olivines. The value indicated is 14,000 cal. per mol for both forsterite and fayalite, from which 100 cal. per gram and 69 cal. per gram respectively are obtained. An estimate based on refractive-index measurements has been made of the change of volume of the more magnesian olivines upon melting, the value 3 per cent being indicated, and with these two factors as a basis the change of melting-point of forsterite with pressure is calculated as 4.7° per 1000 atmospheres.

The optical properties of the several phases have been determined and are presented in tabular and graphic forms.

Brief mention is made of the application of the results to slags and refractories.

(870) The influence of the concentration and nature of the solute on the compressions of certain aqueous solutions. R. E. Gibson. *J. Am. Chem. Soc.* 37, 284-293. 1935.

This paper is one of the series on the general subject of the behavior of systems of two components under high pressures, a topic which was considered in some detail in last year's Annual Report. Experimental measurements of the compressions to 1000 bars of various solutions of sixteen salts and of acetic acid over the whole range of concentration are reported and discussed. The following features of general interest were observed. Within experimental error the apparent compression of the salt varies linearly with the square root of the number of grams of salt per cc of solution. Only in the case of barium thiocyanate and strong solutions of lithium chloride is this relation not evident; it even holds for acetic acid in solutions varying in concentration from 0 to 40 per cent of acid.

The effects of different salts on the compression of water increase with the charge on the solute ions and decrease with the ionic radius, but other factors undoubtedly influence the magnitude of these effects.

The hypothesis that the solute exerts an internal pressure on the water in the solutions continues to receive support from these results. The magnitude of this "effective pressure" varies linearly with the product of the concentrations of salt and water in each solution and the "effective pressure" hypothesis gives an equation whereby the compressibility of the solutions at 1 atmosphere may be computed from the compressions to 1000 atmospheres, excellent agreement with direct measurements, where such are available, being obtained.

Solutions of acetic acid behave under pressure very much like solutions of strong electrolytes. In this case it is not possible to calculate the "effective pressure," but the relative departures from the Ideal Laws of Mixtures for compressions were found, like the "effective pressure" of salt solutions, to vary linearly with the product of the concentrations of acid and water in the solutions.

(871) Glass as a dielectric. George W. Morey. J. Franklin Inst. 219, 315-330. 1935.

A critical discussion of the electrical resistivity of glass as a function of composition and temperature, and of the behavior of glass as a dielectric.

(872) Reading device for burets. Walter P. White. J. Am. Chem. Soc. 57, 332. 1935.

A background which is light above and dark below makes the meniscus in a water-filled buret appear especially distinct, but the apparent position of the meniscus shifts up and down with the background, so that it is necessary to place the background always the same distance below. If the dark part of the background is *horizontal* and of considerable extent, it does not need to be located so exactly. A large cork sliding on the buret, with its top darkened, and carrying a white vertical card, gives good conditions very easily.

(873) Non-silicates with cristobalite-like structure. Tom. F. W. Barth. J. Chem. Physics 3, 323-325. 1935.

In this paper it has been shown that the cristobalite type of structure is not restricted to silicates only, but that at least two aluminates, $K_2O \cdot Al_2O_3$ and $Na_2O \cdot Al_2O_3$, and one ferrite, $K_2O \cdot Fe_2O_3$, crystallize with the same structure.

(874) The leads and the formula in electric calorimeter calibration. Walter P. White. Rev. Sci. Instr. 6, 142-143. 1935.

In precise electric calorimeter calibration it is necessary to measure the potential drop between two points inside the calorimeter chamber, and fine wires have been run to these points for the purpose. It is simpler and more convenient experimentally to attach more robust wires outside the jacket, taking account of the definite and very small potential drop to the two points inside. The only error comes from the change of resistance with temperature of the short intervening portions of copper wire. This error may rarely be large enough to make the method undesirable, but this occurs only when conditions are quite unsatisfactory in other respects. Otherwise, the error is completely negligible.

An apparently new formula for calculating calibration results is given. Though rigorous, it is about as convenient as any, and it shows immediately the error of other formulas, which have generally been approximate.

(875) The igneous rocks in the light of high-temperature research. Norman L. Bowen. Sci. Monthly 40, 487-503. 1935.

After a description of the various manifestations of igneous activity, the chemical and mineralogical characters of the rocks formed as a result of such activity are briefly discussed. The great diversity of these rocks and the relationships observed within certain groups present a problem whose solution requires laboratory study of minerals at high temperatures. These studies of physico-chemical equilibrium in pure synthetic minerals and mineral mixtures demonstrate that fractional crystallization of magmas (molten rock substance) may give rise to great diversity of mineral composition in

rock series formed from an individual magma and show also that the kind of relationship found in natural rock series is often such that it can be referred to the process of fractional crystallization. Brief mention of the nature of these relationships is made and the apparent promise of further investigation along similar lines is pointed out.

- (876) Polymorphism in the FeS-S solid solutions I: Thermal study. Howard S. Roberts. *J. Am. Chem. Soc.* 57, 1034-1038. 1935.

The series of solid solutions that includes the minerals troilite and pyrrhotite extends from the compound FeS to approximately the composition $\text{FeS}_{1.14}$ at 300° . Thermal analyses of synthetic materials indicate that these solid solutions appear in six different forms between room temperature and 575° . However, thermal data alone are inadequate to preclude the possibility that one or more of these "forms" may in reality be a mixture of two distinct solid phases in equilibrium. A prompt, reversible transformation takes place in all these compositions between 315° and 318° and there is strong evidence that the form *b*, stable just above 318° , is not the form *a* which is synthesized at 550° to 575° . In the compound FeS the form *c*, stable just below 315° , transforms reversibly between 144° and 139° to a new form *d* which appears to be the stable form of all these solid solutions at room temperature. With increasing sulfur content, the temperature of this transformation is lowered and it becomes very sluggish. From FeS to about the composition $\text{FeS}_{1.08}$ the transformation is between forms *d* and *c*; at the latter point an intermediate form *e* appears and beyond about $\text{FeS}_{1.07}$ the transformation is between form *d* and an additional intermediate form *f*. Temperatures of transformations $c \rightleftharpoons e$ and $e \rightleftharpoons f$ are raised by increasing sulfur content, reaching the limit of solid solution very close together a few degrees below the $b \rightleftharpoons c$ transformation.

- (877) Volatilization and the constitution of glass. A reply. George W. Morey. *J. Am. Ceram. Soc.* 18, 173-174. 1935.

A discussion of certain conclusions concerning the presence of compounds in glass.

- (878) Equilibrium relationships of Fe_3O_4 , Fe_2O_3 , and oxygen. J. W. Greig, E. Posnjak, H. E. Merwin and R. B. Sosman. *Am. J. Sci.* 30, 239-316. 1935.

This paper presents the results of a study of the equilibrium relationships of Fe_3O_4 , Fe_2O_3 , and oxygen over a limited range of high temperatures. The conditions at equilibrium are represented graphically.

At 1075° magnetite (solid solution) containing 92 ± 1 per cent Fe_3O_4 , 8 ∓ 1 per cent Fe_2O_3 can coexist in equilibrium with hematite containing less than 0.5 per cent of Fe_3O_4 and oxygen under a low pressure (exact value unknown). As the temperature is raised the magnetite in equilibrium with hematite and oxygen becomes considerably richer in oxygen while the hematite (solid solution) in equilibrium with it becomes very slightly lower in oxygen content. At $1452^\circ \pm 5^\circ$ magnetite containing $70 + 2$ or -1 per cent Fe_3O_4 , $30 - 2$ or $+1$ per cent Fe_2O_3 is in equilibrium with hematite containing less than 1 per cent of Fe_3O_4 and with oxygen at one atmosphere pressure. The extent of solid solution has not been traced above or below these temperatures.

Magnetite, corresponding to the formula Fe_3O_4 , melts to a liquid of the same composition at $1591^\circ \pm 5^\circ$ under a small but undetermined pressure of oxygen. Magnetites containing more oxygen melt at slightly lower temperatures, the liquid with which they can coexist in equilibrium being richer

in oxygen than the crystals. The melting temperature of hematite has not been determined; however, it appears to be below that of platinum. A eutectic is formed between magnetite (solid solution) and hematite, but the exact compositions of the phases, as well as the temperature and oxygen pressure, have not yet been determined.

In the course of the determination of the equilibrium conditions, and partly as a necessary preliminary to the planning of the experiments designed to determine these conditions, a number of observations were made that, from their nature, can not be recorded on the equilibrium diagram. Some of these are noted in the discussion of the experiments; others in a descriptive section at the end of the paper. These include notes on oxidation, dissociation, sintering or recrystallization, and unmixing, and on the structures developed by these processes as seen under the microscope; notes on the indices of refraction and color of hematites, on X-ray spectrograms of the oxides, on errors found in analyses made by the Mitscherlich method, on the effect of crucibles of platinum and of rhodium on charges of magnetite, on the volatilization of platinum and rhodium in oxygen, and on the consequent effect on the thermocouples.

- (879) The glassy phase in the manufacture and use of refractories. George W. Morey. *Bull. Am. Ceram. Soc.* 14, 202-206. 1935.

The material which appears as glass when a refractory is cooled is manifestly a liquid at high temperatures, and as such plays an important part in the manufacture and destruction of refractories. Because of the inherent viscosity of silicate liquids, it may be a source of strength at temperatures below the true melting point, a property which gives the silicate refractories their wide range of usefulness. Glass appears early in the burning of a clay, and plays a dual rôle. On the one hand, it serves as a bond; on the other hand, it is a corrosive liquid, which promotes reaction between the components of the refractory, at lower temperatures increasing the density and strength, while at higher temperatures it causes the destruction of the refractory. When used for the manufacture of glass, the life of the refractory depends in large measure on the rate of mixing of the more viscous glass which is part of the refractory with the more fluid glass being melted.

- (880) Vestige of a Pleistocene thermal activity in Iceland. Tom. F. W. Barth. *Trans. Am. Geophys. Union*, 16th Annual Meeting, pp. 284-288. Nat. Res. Council, Washington, D. C. 1935.

The present-day volcanicity in Iceland dates back to early-Glacial times, and it would seem reasonable that this Glacial volcanicity had been accompanied by thermal activity. But no trace of inter-Glacial (or pre-Glacial) thermal activity was known from Iceland; the silica sinter deposits, for example, are all post-Glacial.

However, during the summer of 1934, the writer found, in some inter-Glacial moraine deposits, several boulders of basalt characteristically altered by hot-spring action, thus affording direct evidence of hot springs being active in Iceland as early as in Glacial times.

- (881) Preliminary report on equilibrium-relations between feldspathoids, alkali-feldspars, and silica. J. F. Schairer and N. L. Bowen. *Trans. Am. Geophys. Union*, 16th Annual Meeting, pp. 325-328. Nat. Res. Council, Washington, D. C. 1935.

Phase equilibrium relations in the system, $\text{NaAlSi}_3\text{O}_8$ - KAlSi_3O_8 - SiO_2 , are presented in diagrams. These throw considerable light on the composition

of natural nephelite, on the pseudo-leucite reaction, and on possible courses of crystallization in alkaline magmas.

The composition of nephelites obtained may be expressed in terms of the molecules $\text{NaAlSi}_3\text{O}_8$, KAlSi_3O_8 and $\text{NaAlSi}_2\text{O}_6$. As a result of the incongruent melting of KAlSi_3O_8 the field of leucite extends to compositions considerably richer in silica than KAlSi_3O_8 and all alkali feldspars containing more than 47 per cent KAlSi_3O_8 melt incongruently with separation of leucite. The minimum-melting alkali-feldspar has approximately the composition $\text{NaAlSi}_3\text{O}_8$ 70 per cent— KAlSi_3O_8 30 per cent.

(882) Annealing of Pyrex chemical resistant glass. George W. Morey. An X-ray study by B. E. Warren. *Ind. Eng. Chem.* 27, 966-971. 1935.

The annealing constants of Pyrex chemical resistant glass have been determined, and explicit directions are given for the annealing of apparatus made from it. A sample of Pyrex chemical resistant glass was annealed at 430° , at which temperature it required two years for the removal of most of the strain. After an initial period of about six weeks, the birefringence diminished in accordance with the empirical equation derived by Adams and Williamson. This initial period of more rapid release of strain is usually found, even at temperatures at which the glass anneals rapidly, but in the experiment lasting two years it is more clearly separated from the straight-line part of the annealing curve. The initial period may correspond with the time required for the glass to reach the equilibrium condition for the given temperature, a process which takes place more rapidly than does the actual annealing, while the straight-line portion may correspond to the release of stress in a glass under equilibrium conditions. The theory of annealing is discussed briefly, and a possible alternative explanation mentioned. An X-ray study by B. E. Warren, of the glass which had been annealed for two years at 430° , indicated that no crystallization had taken place, but that there had been a slight increase in regularity in the atomic distribution.

(883) The compressions and specific volumes of aqueous solutions of resorcinol and methanol at 25° and the behavior of water in these solutions. R. E. Gibson. *J. Am. Chem. Soc.* 57, 1551-1557. 1935.

Hitherto the binary systems that we have studied under pressure have consisted of electrolytes and water. This paper extends the work to solutions of two non-electrolytes in water and reports results which show that aqueous solutions of resorcinol and of methanol differ radically in behavior from aqueous solutions of salts or acids.

The specific volumes and compressions of six solutions of resorcinol and fifteen solutions of methanol in water have been measured at 25° and the corresponding apparent and partial quantities computed. The apparent compression of resorcinol varies only slightly with concentration and an equation linear in the square root of its concentration expresses this variation within experimental error. The apparent volumes of resorcinol and the apparent volumes and compressions of methanol in aqueous solutions are certainly not linear functions of the square roots of their concentrations. On the other hand, the curves of the apparent compressions and the apparent volumes of water in methanol solutions against the square root of the concentration of water are S-shaped but have the region of inflection so drawn out that a linear function gives a very fair representation of the data even over the whole concentration range.

Analysis of the effect of concentration on the partial volumes of the components indicates that methanol and resorcinol promote the association of

water, thereby differing from most other solutes. This effect is correlated with the variation with concentration of other significant properties of these solutions. It is noteworthy that the specific compressions (to 1000 bars) of all solutions of methanol from 0 to 15 per cent are the same as the specific compression of pure water.

New values of the compressions of pure methanol at various pressures up to 1000 bars are given and it is pointed out that these do not agree with values already in the literature.

- (884) Grunerite from Rockport, Massachusetts, and a series of synthetic fluor-amphiboles. N. L. Bowen and J. F. Schairer. *Am. Mineral.* 20, 543-551. 1935.

Grunerite associated with the fayalite of Rockport, Massachusetts, has been analyzed and its properties have been determined. Just as the fayalite of this locality approaches the pure ferrous end-member of the olivine series, so the grunerite is found to approach the pure ferrous end-member of the amphibole series. This grunerite is therefore of especial value for the construction of a graph of the properties of the cummingtonite-grunerite series.

In addition to the natural hydroxy-amphibole a series of fluor-amphiboles, prepared in the laboratory, has been studied. These extend from the pure magnesian member to the pure ferrous member. Their optical properties have been determined and are compared by means of diagrams with those of the hydroxy-amphiboles.

- (885) Note on the structure of dickite and other clay minerals. C. J. Ksanda and Tom. F. W. Barth. *Am. Mineral.* 20, 631-637. 1935.

The structures of dickite and other clay minerals hitherto proposed were all based on powder spectrum diffraction data. Such data, however, are not sufficient to establish uniquely the crystal structure of monoclinic minerals with many parameters.

The present paper supplies new experimental evidence from a *single* crystal of dickite using an X-ray goniometer of the Weissenberg type, and X-ray data thus obtained are given and compared in detail with work previously published by Gruner. The new X-ray data permit the following conclusions: The geometrical elements and dimensions of the unit cell of dickite have been correctly determined by Gruner. Dickite is composed of discrete sheets of cations and anions parallel to the $a-b$ plane stacked on top of each other in the manner described. However, the two-dimensional arrangement of the several atoms within each sheet is different from any of the arrangements considered by Gruner, and since the crystal structures of kaolinite, nacrite, vermiculite, and halloysite have been calculated on the basis of the structure of dickite, the proposed structures of all these clay minerals can not be accepted as being correct without further proof.

- (886) The problem of the intrusion of dunite in the light of the olivine diagram. N. L. Bowen and J. F. Schairer. *Rept. 16th Int. Geol. Congress*, 1933.

It has long been known that the melting temperature of pure magnesium olivine, Mg_2SiO_4 , is approximately 1890° . This fact, taken in conjunction with the lack of evidence of excessively high temperatures in dunitic and closely related igneous masses, has raised the question whether these masses were ever completely liquid as such. The difficulties involved in the concept that they were liquid are somewhat mitigated by assuming that the fayalite molecule, Fe_2SiO_4 , which is usually present in significant amount in the olivines, effects a very marked lowering of the melting temperature of olivine.

Thus we owe to Vogt a hypothetical diagram in which only 20 per cent of the fayalite molecule is sufficient to lower the melting temperature of the olivine to about 1500° . Remelting of accumulated olivine crystals at some such temperature has therefore been accepted by many petrologists as a possible mode of origin of dunitic liquid.

The actual olivine diagram has now been determined. Its character is definitely at variance with the suggestion of Vogt. A content of about 75 per cent of Fe_2SiO_4 is required in an olivine to lower the melting temperature to 1500° , and with only 20 per cent of Fe_2SiO_4 the melting temperature exceeds 1800° . Whether the advocates of the doctrine of the intrusion of dunitic and closely related liquids may still find that doctrine acceptable, in the face of such figures, is a question for the future. In the meantime it seems preferable to turn to other hypotheses of the mode of intrusion of dunite and its near relatives. Some of these hypotheses are suggested and discussed.

(887) The large pre-Cambrian intrusive bodies in the southern part of Norway. Tom. F. W. Barth. Rept. 16th Int. Geol. Congress, 1933.

These intrusives form the southwestern extremity of the Fenno-Scandian shield and afford a good example of pre-Cambrian rock types the composition or mode of emplacement of which is very different from anything observed in rocks of later date.

During several years of work, much information about these rocks has been assembled, but unfortunately the limited space does not permit inclusion in the present paper of petrographic descriptions of the various types of rocks encountered in the area or an adequate presentation of all the evidence gathered in the field and in the laboratory. The paper has therefore been restricted to a brief survey of the facts from which the mode of invasion and probable origin of the different rocks have been deduced.

The rocks consist of (1) granites and granitized gneisses, (2) banded gneisses, and (3) anorthosite and congenetic rocks.

The mode of intrusion of the granitic magmas has been different from that of the ordinary magmatic intrusions of later date. Thus there has not been any definite single period of intrusion, with consequent brecciation of the walls and formation of "flow lines" in the solidified rock. The magma, which in general originated by anatectic processes (differential re-fusion), was passive but was able to soak through the adjacent rock masses, partly altering them metasomatically, partly forming migmatites and gneisses, and partly concentrating in larger bodies of pure granite.

The banded gneisses are regarded as the solid residues after this differential re-fusion with the consequent squeezing out of the granitic liquid.

At a much later time a magma with abundant suspended crystals in it rose from some unknown depth in the west. The bulk composition was quartz dioritic, but during the injection and squeezing out the suspended crystals, largely plagioclase, became separated from the mother liquor, and anorthosite was formed. The intrusion was accompanied by quite an appreciable amount of brecciation, disintegration, and assimilation of the country rocks. Only through deep erosion of the pre-Cambrian shield are these rocks now exposed to the light of day.

(888) Annual Report for this year.

(889) Hot springs of the Yellowstone National Park. E. T. Allen and Arthur L. Day; microscopic examinations by H. E. Merwin. Carnegie Inst. Wash. Pub. No. 466. 515 pp., 215 illustrations. 1935.

A detailed discussion of the hydrothermal phenomena in an outstanding field. Following a preliminary narrative of early geological work in the Yellowstone Park, especially that of the U. S. Geological Survey, a chapter is devoted to general description, and another to a résumé of the most important hot-spring theories thus far proposed, including a hypothesis previously formulated, and here further developed, by the writers.

Attention is given to steam jets, particularly the super-heated ones, about a dozen of which have been found in the Park, and their bearing on hot-spring theory. From what is regarded as a substantially complete survey of the thermal ground, with measurements and estimates of discharge, an obvious relation of the latter to local topography has been found. Combined with numerous temperature measurements these discharge figures enable us to compute approximately the heat dissipated in the hot areas, while discharge measurements and water analyses lead to a value (first approximation) for the dissolved material carried away by the drainage.

A representative series of hot-spring gases has been collected and analyzed and the chemical work of Gooch and Whitfield on the hot mineral waters has been greatly extended. Considered with the composition of the adjacent rocks, these data point the way to a rational derivation of the mineral matter in the springs. The deposits studied chemically, optically, and in many instances by means of X-rays (the last by Eugene Posnjak), are seen to be for the most part directly related to the rocks, though certain of the minor ones originate wholly or partly in the magma.

Differentiation of hot-spring areas into distinctive types is a subject scarcely touched since Bunsen's time. The writers have endeavored to show that these types may be plausibly explained as due to differences in the magnitude of the water supply and differences in the volatility of the magmatic emanations.

The investigation as a whole makes it clear that hot springs and fumaroles are vitally related to other stages of volcanism, not only because they are all possessed of subterranean heat, but also because the gases common to them all afford the only interpretation of their behavior.

The cause of geysers is not, as many suppose, a settled question. Earlier critics have shown that Bunsen's theory does not satisfactorily account for geyser behavior and have suggested important changes in the theory. Most of the well-known facts and new ones discovered by the writers are explained by Lang's hypothesis (Göttingen 1880), but the fluctuations in behavior apparently common to all geysers have seemingly never been discussed by other investigators and still remain a mystery.

In Part II of this volume the various hot-spring groups of the Park are described as individual units, without the generalization of evidence found in Part I. This section may serve as a guide for students of the subject.

(890) The Raman spectra of oxalic acid. James H. Hibben. *J. Chem. Physics* 3, 675-679. 1935.

The Raman spectra of oxalic acid were determined in order to define more clearly the constitution of the molecule and as an example of the application of the Raman spectra method to chemical problems. It is well known that the generally employed formulæ $(\text{COOH})_2$ and $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$ for anhydrous and hydrous oxalic acid fail to explain all their chemical properties.

A number of Raman lines were obtained from the anhydrous oxalic acid, the dihydrate of the acid, and aqueous and alcoholic solutions of oxalic acid. One frequency shift $\Delta\tilde{\nu}(\text{cm}^{-1})$ 850 is common to all. This is attributed to the

C \longleftrightarrow C oscillation. Two other prominent shifts were observed in the aqueous solution and from the anhydrous acid. These were $\Delta\tilde{\nu}$ 1655 and 1740 and are assigned to the carbonyl (C=O) oscillation. The simultaneous presence of two such shifts from similar groups is unique and is strong evidence in favor of the dissimilarity in behavior of the two carbonyl groups. The magnitude of the $\Delta\tilde{\nu}$ 1740 shift indicates a force constant between the carbon and oxygen of an unusually high value and this would reasonably account for the strength of this acid.

A comparison of the intensities of the $\Delta\tilde{\nu}$ 1655 and 1740 shifts in the aqueous solution and from the anhydrous and hydrated crystalline material indicates that the number of normally behaving carbonyl groups in the crystals is much less than in solution. Several possible explanations of this fact are discussed. The most logical explanation involves a partially continuing structure in the crystalline material resulting from a chelation of the C=O and OH groups. This chelate structure breaks down in solution.

The alcoholic solution of the acid shows one single frequency characteristic of the carbonyl grouping, namely, $\Delta\tilde{\nu}$ 1750. This indicates that both carboxyl groups in the acid function similarly in alcoholic solution and that oxalic acid should be a stronger acid in alcohol than it is in water.

(891) The eruption of Mt. Pelée, 1929-1932. Frank A. Perret. Carnegie Inst. Wash. Pub. No. 458. iv+126 pp., 71 illustrations. 1935.

A record of almost continuous observation, much of it at close range. This volcanic eruption was characterized by two distinct phases, probably common where the lavas are of acid type, one following the other with some overlapping. First in importance is the more violent explosive phase, the *nuées ardentes* of Lacroix, intensely hot dust clouds, concealing formidable avalanches of lava and ash, explosively expelled from the crater, rushing at high speed down the mountain slope to distances of several miles. The lava involved in these avalanches is conceived to be highly charged with volcanic gases, which in their expansion lift the mass from the crater, continue to escape as long as temperature permits, and convert the lava partly into ash, surrounding each particle with a highly compressed cushion. On these cushions the avalanche moves, frictionless and noiseless, except where barriers are encountered, or when conditions give rise to strong electrification which is attended by brilliant flashes and crashing discharges.

Beginning when the *nuées ardentes* had greatly declined in power and frequency, a milder phase of dome- and spine-building succeeded and finally replaced the former entirely. Lava relatively free from gas was slowly pushed upward, forming a dome, the crust of which was now and then punctured by the upthrust of spines of various sizes. The chief force in action here is believed to be gravity working toward isostatic adjustment, though gas pressure is regarded as an important contributory factor.

From a knowledge of the type of an active or quiescent volcano and its past history, the author believes it possible to diagnose its present condition and to predict its behavior in the near future. By the application of an earth microphone, a seismograph and other means, he has made successful predictions in a number of important cases. Arriving at Pelée late in 1929, he concluded after a preliminary investigation that the paroxysmal eruption of 1902, when the accumulation of centuries was blown from the vent, should be followed by a period of gradually declining activity, a prophecy borne out by subsequent events.

DIVISION OF HISTORICAL RESEARCH¹

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America and the Pueblo area of southwestern United States. The Section of United States History conducts research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoordinated data which bear upon the acquirement and transmission of ordered knowledge.

SECTION OF ABORIGINAL AMERICAN HISTORY

To the panscientific survey which the Section is carrying on in the Maya field there have been added, during the past year, two important new activities, the Copan Project and the Maize Survey.

The Copan Project, under the direction of Mr. Stromsvik, is a joint undertaking of the Government of Honduras and Carnegie Institution, the Institution's share of the expense being covered by a grant from Carnegie Corporation. At Copan, one of the greatest centers of Old Empire culture, the Institution is continuing its effort to conserve and make available for scientific study and lay observation outstanding examples of the architectural and sculptural art of the ancient Maya. The repair of the Temples at Chichen Itza was done for the same purpose, as was the mending and re-erection, in 1934, of the stelæ at Quirigua. Copan fits well into this program, for its sculptures are not only among the finest ever produced by the Maya, but were also in urgent need of attention, many of them lying so broken and scattered by earthquakes and the impact of falling trees that their beauty could not be appreciated, nor could it be hoped that their fragments would long survive the destructive effects of brush fires and exposure to the weather. Results of Mr. Stromsvik's very effective work during the past season are presented in a later section. Here should most warmly be acknowledged the invaluable cooperation of the Honduran Government, which has provided all labor and free transportation from the border of all equipment and supplies. Furthermore, the Minister of Education, Dr. J. Rodriguez, and President Carias' personal representative, Sr. Carlos Izaguirre, repeatedly visited Copan during the season to confer with Mr. Stromsvik and to see that everything was being done to facilitate the work.

The second new development was establishment of cooperation with the United States Department of Agriculture. Through the good offices of Secretary Wallace and of Mr. Knowles A. Ryerson and Mr. Frederick D. Richey, former and present Chiefs of the Bureau of Plant Industry, the Institution is privileged to have the assistance of Messrs. Collins and Kempton for attack upon the fundamentally important question of the

¹ Address: Room 909, Tower Building, Washington, D. C.

origin of maize and to make studies of the maize agronomy of the Maya area. Maize was the cereal which made possible the rise of pre-Columbian American civilization, but its ancestry is problematical and we do not certainly know where, nor even approximately when, it was first brought under cultivation. Thus we can do little more than theorize regarding the place or the time of the beginnings of the higher New World cultures, including, of course, that of the Maya. And the whole career of the Maya, like that of any farming people, must have been most potently influenced by the agronomic possibilities of the lands they cultivated and by the methods which they worked out for growing their staple crop. Without data upon these subjects, gathered by experts, it is impossible to make reliable estimates of size and distribution of population, or to understand the probable way of life of the ancient people.

The Copan Project and the Maize Survey add to a group of researches which was already extensive. The Division is now active archæologically in the Mexican states of Yucatan and Campeche; in Guatemala in the Highlands of Petén; in Honduras. It has also, in cooperation with Field Museum, been conducting excavations in British Honduras. In addition, it is carrying on, independently or with other institutions, studies of the documentary history of the Maya, ethnological and linguistic investigations in Yucatan and Guatemala, work in human geography in the same regions; as well as gathering data, whenever opportunity permits, upon the climate, geology, health conditions and the botany and zoology of the Maya area.

This heavy and varied program has been undertaken with belief that in any historical study one must utilize the resources of many disciplines and take advantage of all possible side-lights. Our investigation, however, is frankly experimental, in that it still remains to be determined whether or not the practical and intellectual difficulties of a coordinated panscientific survey can successfully be overcome. Facts, of course, will accrue in abundance. If they be intelligently gathered and clearly set forth, we shall have added significantly to the sum of recorded knowledge. But shall we be able to digest our masses of raw data in such a way as to reach understanding of the all-important whys and wherefors of Maya history and by so doing contribute toward comprehension of the infinitely complex interaction of those biological, environmental and social forces which govern the evolution of man?

Obviously, synthesis and interpretation should be the ultimate goals of all historical research. Particularly must they be held as objectives during prosecution of such a program as ours. For each investigator is brought so quickly into virgin fields, is confronted with so great a body of intensely interesting and puzzling new material that he runs the constant danger of immersing himself in blindly intensive specialization. And in the same way that the individual worker risks entanglement in detail, with indefinite postponement of the essential process of reaching conclusions, so the program as a whole may easily expand and ramify to such an extent that correlation becomes impossible.

The element of time must also be taken into account. The materials of Maya archæology are practically inexhaustible. Profitable excavation

could go on for a century. Environmental studies, in a region of such diverse topography and climate, might be continued without limit. Furthermore, one of our principal tasks is the gathering of information as to present-day conditions in Central America. This is undertaken to throw light upon the past, and also because the region forms an ideal field for research upon problems of racial and cultural contacts which are of fundamental importance for the modern world. And here again one sees no place to halt our researches, for the present is always with us, change is constantly going on, significant new phenomena develop from year to year.

There is, then, no clearly discernible stopping place for our work, either in space or in time. Certainly the project should be continued for a number of years. There are certain known gaps in our knowledge which must be filled. Many data have to be accumulated before synthesis can become worth while. A considerable period is required to assemble a group whose members can, by practical experience, be brought to see the benefits of close intellectual cooperation and the pooling of information. So, there being no natural termination for our program, it seems necessary to set an arbitrary time limit by establishing a date when each investigation shall come to a close, all findings be recorded, definite conclusions be stated, and formulation be made of problems for future research. Ten years are believed sufficient to permit current researches to be carried to this stage. New projects will only be undertaken if they can be completed within that time. The arrangement will insure that the older members of the Section's staff shall have completed their work at retirement. And for the younger men it should also be of benefit, for it is good for any student periodically to bring his research to a head, check up, draw conclusions, and make a fresh start.

The above decision implies no doubt on the part of the Chairman regarding the value of the Section's program, nor any feeling that it should be discontinued at the close of the ten-year period. The pause is designed to permit ourselves and our colleagues to judge whether or not the project is so conceived and so prosecuted as to give promise of attaining the historical results for which it was undertaken. The conclusions which we present should also enable the Trustees of the Institution to reach decision as to the nature and scope of future activities in Aboriginal American History.

There follow reports upon the work of the period from July 1, 1934, to June 30, 1935.

MAYA RESEARCH

UAXACTUN—A. L. SMITH

The tenth season at Uaxactun opened on February 23 and closed on May 18. The work was in charge of A. Ledyard Smith; Robert E. Smith and Francis B. Richardson served as assistants and Edwin Shook as surveyor.

The greater part of the season was devoted to continuation of the excavation of Structure A-V, the so-called "Palace." This great multi-chambered building was originally chosen for investigation because no Old Empire example of its type had previously been excavated. Work on A-V

began at the end of the 1931 field season and continued through the winters of 1932, 1933 and 1934.¹

At the close of the past season the whole outer structure of A-V had been uncovered, and earlier walls and rooms were exposed behind walls and under courts of later construction. In 1932 and 1934 some work had been done on these and four distinct types of superstructures had been found in stratigraphic position.²

The program for 1935 called for further investigation of the remains of the older buildings, and search for the nucleus from which the Palace started. It was also hoped that the pottery found in association with the various periods of construction would amplify, and serve as a check upon, the Uaxactun ceramic sequence that had been built up as result of the Institution's previous excavations. Work progressed satisfactorily. A wide trench, cut through the north side of the Palace at ground-level, gave access to the Buried Court, facilitating removal of dirt and providing an excellent cross-section of the building.

By the end of the season a number of rooms had been cleared, a new buried pyramid had been uncovered, and the whole northeast and part of the northwest corner of the Period III substructure were exposed. This very impressive platform proved to be faced with well-cut stones laid up on a batter and to rise, with the interruption about midway of a narrow terrace, to about 22 feet above the level of the East Court. Its two exposed corners are inset and rounded. The platform supports another low platform which in turn supports eight Period III rooms.

The masonry of the various types of substructure proved to be of great interest and much was learned regarding the quality and amount of lime cement used and as to fills interpolated between binding layers. Rough walls, it was found, were built within the hearting to keep the fill in place during construction, and wooden beams were placed horizontally in the fill as an added support. Substructures were carefully observed in relation to their superstructures. Substructures, like superstructures, changed in their type of construction, the succession being in general from large rough stones laid horizontally and deeply set into the hearting, to thin veneers of well-cut blocks. With further investigation it should be possible to establish a definite correlation between superstructure and substructure masonry so that if only one is visible the type of construction used in the other would be known without excavation.

To date, 62 rooms, 14 buried rooms, 5 shrines, 2 buried shrines, 4 courts, 1 buried court, 3 dated stelæ, and various caches and burials have been found in the Palace.

During the past season 23 burials came to light. These were of all types and all periods and ranged from adults of both sexes to babies. There was one instance of a mother with foetal child. The positions of the skeletons varied from fully extended to closely flexed. Imprints of the fabrics used to wrap the bodies were found in several cases in the dried mud on the walls

¹ For statements regarding the archaeological significance of Uaxactun see Year Books Nos. 15, 21, 26-33; for accounts of earlier work on Structure A-V see Year Books Nos. 31-33.

² For description of the several types of superstructure see Year Book No. 32.

of the burial chamber. The graves varied from well-made vaulted rooms containing a great many offerings to simple holes in the fill below room or terrace floors. The mortuary pottery is, as a rule, of a more advanced type than that represented by the sherds in fills of the same period; many pieces apparently not of local manufacture are represented. In this one seems to see a predilection, in funerary practise, for novelties and imported wares. Much whole pottery and great quantities of sherds were recovered, which are now being studied in Guatemala City. This work has not been completed, but it may be said that the sequence of types so far found in the Palace follows that previously established at Uaxactun. The two most interesting and beautiful vessels were a red barrel-shaped vase on an annular base, carved with four seated human figures in full costume; and a cylindrical vase of polished black ware covered with a thin coat of plaster upon which a series of figures is painted in pastel shades and with the delicacy and sureness of line characteristic of the finest codex painting. In a cache was found a set of nine obsidian flakes skilfully incised with figures of deities. Such objects have hitherto come to light only at Tikal. From all the evidence so far recovered from the Palace it would seem that the function of this complex building probably changed during the long period of its use. There are strong indications that during its last phase it served as living quarters as well as for religious ceremonies. It has been suggested that the purpose of structures of this type was to house priests and acolytes. They were also undoubtedly used as store houses for the elaborate paraphernalia connected with the many ceremonies carried on throughout the year.

During 1934 most of the superstructure of Temple A-XVIII was excavated and mapped. In 1935 this work was completed. It is an eighteen-room building, two stories high, standing on a large platform. The upper story is reached by an interior stairway. The exterior was decorated with fourteen large stucco masks set in panels. An interesting find made in A-XVIII was three-quarters of a bow which the Department of Agriculture of Guatemala identifies as the wood of the *guayacan* or *cortés negro* tree.

In Group B the excavation of Structure B-ZIII was continued. This one-story building is of two periods and has many architectural features of interest.

In the course of remapping Group B, Mr. Shook discovered two large artificial reservoirs. One of these lies west of the causeway joining Groups A and B and the other is southwest of the Main Plaza of Group B, from which it received the drainage. Group B is built on a natural hill which has been leveled in some places and built up in others. A possible ball court was located; only slight excavation will be necessary to determine whether or not it is such.

There is fairly good evidence of two roads, one from the west and one from the north, leading into Group B. These are artificially leveled areas extending out into the bush. They are comparable to the entrances into an Indian town of today, where the paved streets run a short distance beyond the town and there join the trails and rough roads of the surrounding country. There is no evidence at Uaxactun of any such long and well-made highways as the *sacbes* of Yucatan.

Material was gathered for an attempted time-correlation, by means of potsherds, of the various major groups of structures at Uaxactun. Robert Smith carried on this work by means of test pits in plazas and trenches into mounds. At the end of the season a preliminary survey was made of a new group (H) discovered about 225 yards south of Group E. It consists of two separate plazas surrounded by mounds of considerable size.

COPAN—GUSTAV STROMSVİK

The work at Copan in western Honduras was undertaken, in cooperation with the Honduranian Government, for two purposes: to repair and protect the remarkable stelæ and other monuments for which these ruins are famous; and to secure data bearing on fundamentally important problems of Maya sculpture, architecture and ceramics.

Copan is a classic site for Maya archaeology. It was first brought to general notice by Stephens' and Catherwood's pioneer investigations; Maudslay's unrivaled photographs and drawings of the Copan sculptures, made in the 80s, gave tremendous impetus to Maya research; in the 90s extensive excavations were carried on at Copan by the Peabody Museum of Harvard University; Spinden based his great work on Maya art very largely upon the Copan carvings; and Morley made its inscriptions the subject of the first of his exhaustive epigraphic monographs. In spite of so much activity, neither the "dirt archaeology" of Copan itself nor the relations of the city to other centers of Maya development is adequately known, for the work of the Peabody Museum was done before the introduction of modern methods of excavation, and both Morley and Spinden confined their studies to single aspects of culture. The current project should therefore result in accumulation of many significant new data. The first year was devoted primarily to such repairs as were most urgently necessary; reassembly and reerection of the many broken, fallen and leaning stelæ; and preliminary steps to prevent further destruction by the Copan River of the enormous mound known as the Acropolis.

Mr. Stromsvik, assisted by Mr. Deric Nusbaum, was in the field from January to June, inclusive. Equipment, tools and food-supplies were bought in New Orleans and shipped through Guatemala by rail to Chiquimula, whence they were transported across the mountains to Copan by the Government of Honduras.

Actual work started on January 15th. The ruins, being completely overgrown, had carefully to be cleaned before an adequate idea could be formed as to the number of damaged monuments which required attention. Timbers for tall stout scaffoldings were assembled, and Col. Antonio Sans, paymaster and representative of the Government arrived with two picked masons. By the end of January the repair was well under way, starting with Stela 4 in the Great Plaza, a monument very badly broken by its fall and repeated milpa fires.

An excavation was also started under the base of Stela A, on the east side of the Plaza. This stela was leaning so badly, apparently as result of a recent severe earthquake, that it was in danger of falling, as were Stelæ H and P. One of the first steps was therefore to secure these stelæ with

stout wooden braces until they could be straightened and their bases strengthened. Earthquakes occurred almost daily, in stronger and weaker degrees.

In order to straighten a stela, the butt must be freed on all sides to allow it to be restored to vertical position without undue strain upon the tall stone shaft. In such clearing of their bases excellent opportunities were afforded for study of the manner in which stelæ had originally been erected, and for observations of the cruciform offertory chambers usually found beneath them. Eighteen stelæ were thus examined for dedicatory offerings. These proved, for the most part, to consist of pottery vessels, the majority of crude ware, a few of finer workmanship. Other objects found in the cruciform vaults were seashells, coral and disintegrated cinnebar. Probably the most important discovery of the season was the finding, under Stela H, together with some broken beads of jade and other stones, of two tiny gold fragments, the legs of a small hollow figurine, which in complete state perhaps served as a pendent to a necklace formed by the beads. That most of the latter were in pieces, seems to indicate that they were broken ceremonially before being placed under the stela, as most likely was also the gold figurine. Thorough, but unsuccessful, search was made for the rest of the figurine. The bits recovered are the first objects of gold which are definitely assignable to the Old Empire period.

Research upon the specimens, particularly those of pottery, found in connection with the Copan stelæ is outstandingly important, because of the fact that these monuments bear hieroglyphic dates which permit them to be ranked in chronological order. And, when the correlation question has been settled, we shall be able to place them in terms of the Christian calendar. Thus the sub-stela objects, already serialable relative to each other, and doubtless eventually even datable, provide valuable materials not only for determination of the nature and the rate of Maya culture-growth, but also, through comparative study of trade-specimens, to establish cross-links between certain stages of Copan culture and developments in other areas, within and without the Maya field.

Several trenches were dug in the Great Plaza to define relations of the stelæ to the plaza levels, and of the latter to surrounding structures. Many potsherds and fragments of implements came to light, as well as a cache of several hundred large obsidian blades.

Other activities of the 1935 field-season were: restoring of a partly destroyed burial chamber in the East Court, the only accessible roofed structure in the ruins; the laying out and partial supervision of the clearing and leveling of a new flying-field near the ruins; and the fencing of the entire Government reservation, both ruins and flying-field, to keep out cattle and unauthorized visitors. A number of altars and sculptured stones were repaired and examined for ceremonial offerings; and those that had been moved in recent years were restored as nearly as possible to their original positions.

Much thought was given to ways and means of preventing the Copan River from cutting farther into the high bank forming the east side of the Acropolis. Since Maudslay's time, some fifty years ago, the river has

eaten away a strip approximately 10 meters thick by 100 meters long, reaching from the base to the top of the Acropolis, a height of 35 meters. The remnants of two richly sculptured structures have been lost, and much more destruction is threatened. The cut made by the river forms at present the most spectacular and instructive archæological cross-section in the Maya area. The problem of guarding the Acropolis from the assaults of the small but intermittently raging river proved a difficult one. Many plans were formed and discarded, such as building a solid breakwater the length of the exposed face, or chaining a floating protection of boomed logs along its front; but the expense of importing the necessary large quantities of cement and iron was found to be prohibitive. It was finally decided to adopt the radical expedient of changing the course of the river by opening a ditch across a tongue of land to the east. This will bring the channel straight down the valley, some 100 meters away from the ruins. It is thought that a relatively small canal will serve to start the river on its new course, and that it will do most of the necessary digging itself.

MINOR EXCAVATIONS IN GUATEMALA—A. V. KIDDER, O. G. RICKETSON

A check-up of our present knowledge of Maya prehistory, undertaken during consideration of the ten-year plan mentioned in the introduction to this report, reemphasizes the obvious fact that many parts of the area are archæologically almost unknown. It has also become clear that while reasonably satisfactory progress has been made in study of the Maya culture in its full flower during the Old and New Empires, very little light has yet been thrown on the outstandingly important problems of Maya origins and of the cultural and chronological relations between the developed Maya and other advanced groups in Middle America. Work, for example, is urgently needed in the southwestern part of the Yucatan peninsula and along the coastal plain of southern Vera Cruz, regions which should yield information upon early movements into northern Yucatan, as well as upon the source and nature of the later wave or waves of Nahuatl influence. The country lying between the Puuc¹ and the Petén is studded with sites which should answer many at present extremely vexed questions regarding the cultural and time connections of the Old and New Empires. British Honduras, too, while its ruins are not spectacular, has been proved by Thompson to contain much material traded from other parts of the area. Investigation there should therefore provide valuable evidence for integrating our knowledge of Maya archæology, particularly as regards ceramic developments. And the significance of the Guatemala highlands can hardly be overestimated, for in the mountain valleys should be found the remains of the early groups whose culture, according to the hypothesis held by most authorities, either through movement of people or by diffusion, fathered that of the Maya. The highlands, furthermore, seem always to have been the corridor for Middle American migration and trade. Highland sites, as is indicated by Lothrop's recent studies, show influences from both north and south, as well as from the Old Empire region.

¹ For discussion of the specific problems of the Puuc, see reports of field work, pages 124 to 127.

A vast deal of almost virgin territory thus remains to be investigated. To work it at all thoroughly would require a very long time and much greater resources in funds and personnel than are available. Yet we should as quickly as possible obtain some idea of its archæology in order that, within the ten-year period we have assigned ourselves for arriving at the stage of synthesis, we may envisage the major trends of Maya development. Even when no arbitrary time-limit is imposed, the soundest method of attacking any large archæological field is to make an extensive preliminary sampling, for the purpose of locating strategic sites for intensive research. For this reason it is evident that major excavations at large sites should, for the time-being, be discontinued and our efforts be devoted to what may be called reconnaissance digging. The value of this sort of work has already been demonstrated by Messrs. Roberts' and Pollock's ceramic-architectural survey of northern Yucatan.¹ During the past season a similar campaign was inaugurated in Guatemala by reconnaissance investigations at Finca Miraflores in the highlands and at San Agustín Acasaguastlan and Salama in the Motagua drainage.

FINCA MIRAFLORES

The great Miraflores-Arevala mound group near Guatemala City has bulked large in the somewhat speculative writings upon the "Archaic" period and upon the genesis of Maya culture. Its clay figurines and pottery have been compared to those from the Valley of Mexico, from Salvador, from the Uloa Valley, and from the early deposits at Uaxactun. But aside from excavations by Dr. Gamio in 1925, which were stated to have revealed stratified deposits, no "dirt archæology" had been done, nor does there exist any adequate description of the local ceramics.

The site, which lies in the outskirts of Guatemala City, consists of a large aggregation of earthen tumuli, most of which were apparently sub-structures for now vanished buildings of perishable materials. The work of 1935 was confined to test-pitting and trenching in search of refuse accumulations in which it was hoped that materials might be found so stratified as to provide information regarding the nature and the sequence of the several ceramic periods which, according to Gamio, are represented at Miraflores. Best results accrued from the banks of a gully recently opened by seismic action. At that point rubbish extended to a depth of three meters. Careful testing failed to reveal stratification, the material all seeming to emanate from a single culture horizon. However, a very large collection of potsherds was made, as well as an apparently representative series of figurines. This material is of the sort which, rightly or wrongly, has been assigned to an early period. It will be studied during the coming winter. When published, it should give us a valuable datum for further typological research upon highland developments.

SAN AGUSTÍN ACASAGUASTLAN AND SALAMA

Maya culture is at present generally supposed to have been derived from the highlands and to have blossomed in the Petén. If this be so, one must postulate its relatively slow descent into the lowlands, for it is certain that

¹ See Year Books Nos. 30 to 33 and pages 124 to 127 of the present report.

those densely jungled regions could not quickly have been conquered for agriculture. It is therefore to be expected that chronologically and culturally intermediate remains should exist in the territory between the highland and lowland centers; and the country most likely to harbor them should be the upper and middle drainages of the great rivers that head in the mountains and skirt the Petén. An archæological survey of the Motagua and Rio Negro valleys was accordingly begun during the winter of 1935.

The site first investigated lies near the town of San Agustin Acasaguastlan, in the arid Middle Motagua. It is a long and straggling series of rock mounds skirting the Rio Lato, a small northern tributary of the Motagua, which enters the latter just below El Rancho. The constructions proved to be of two sorts: substructure and burial mounds. No traces of early occupation were found, but interesting data were gathered regarding the vaulted tombs contained in the burial mounds. These were small subterranean masonry chambers, roofed with a corbelling of stone slabs, and covered with heaps of rock varying from one to four or five meters high. Two chambers were opened and a number of others, previously cleared by the Guatemala government, were studied. There accrued a small collection of mortuary pottery. The most profitable part of the work, however, was the excavation of two rubbish deposits which yielded a great harvest of potsherds representing the wares in common use at the site. A report on the San Agustin burial chambers has been published.¹

It may here parenthetically be stated that the study of Maya ceramics has to date been sadly handicapped by the fact that practically all conclusions have had to be based on a very few fine vessels from tombs, many of which are most probably trade pieces and practically none of which are representative of the ordinary, everyday run of vessels serving the mass of the population. It is about as though a botanist were forced to draw inferences as to the flora of Long Island from the contents of the green-houses on its country estates. However, such material as was gathered at San Agustin and Salama, and as is being collected at Chichen Itza and in the Puuc, at Uaxactun and Copan, as well as that coming to light in the excavations of the University of Pennsylvania Museum at Piedras Negras, is rapidly supplying a large body of more reliable data for research upon Maya pottery.

The mounds at Salama, some twenty-five miles northwest of San Agustin, are in the drainage of the Rio Negro, which in turn flows into the Usumacinta. They are large earth tumuli, apparently not containing chambers like those of San Agustin. In the short time available it was not possible to make extensive excavations in the mounds, but trenching in their vicinity produced the usual large collection of potsherds.

The work at Miraflores, San Agustin and Salama proved, if nothing else, that even the most modest excavations result in a grist of ceramic material so extensive that months are required to work it up and prepare it for publication. When methods of handling such accumulations have been improved and standardized, when types have been established, and a start has been made toward building up a well-illustrated descriptive literature,

¹ Carnegie Inst. Wash. Contrib. to Amer. Arch. No. 456.

things will doubtless go faster, but at present there seems no escape from long and arduous studies of everything that is found. All of which still further indicates that large-scale digging in the Maya field is not now to be encouraged, for it is certainly better that the ceramic documents, so precious for the reconstruction of Maya history, be left for the time undisturbed, than that they be hauled from the ground with their meaning only half understood, to clutter the basements and attics of museums.

ARCHÆOLOGICAL WORK IN YUCATAN

As was stated in the last Year Book report, the ten years of intensive excavation at Chichen Itza are being followed by an interval for the publication of those units of work which have not yet been treated monographically; and for research upon certain problems raised by the Chichen Itza diggings which can not be solved save on the basis of investigation elsewhere in the Peninsula. The Institution's headquarters at Chichen Itza have, however, been kept open to serve as a base for the field-workers. Dr. Morley was, as usual, in residence. He devoted his time to preparation of his compendious report upon the inscriptions of the Petén, and to further studies, in collaboration with Mr. Roys and Sr. Rubio Mañé, upon the history of the Xiu family, former rulers of the city of Uxmal.

Several conferences were held at Chichen Itza during the spring, when new material gathered by Messrs. Roys and Rubio Mañé was compared, collated and combined with data collected in previous years, and many gaps in the story of this most interesting and ancient family were filled. Sr. Rubio Mañé made an extensive search of all church records in the Xiu region for items concerning the Xius; it is felt that when he has completed his examination of the two hundred and fifty-odd notarial books in Merida, practically all known sources for Xiu material will have been exhausted.

Dr. Morley also excavated a mound near the town of Oxkutzcab, for the purpose of locating, if possible, the site of the church of the former Maya village of San Juan Bautista Yaxacumche, where the Xiu family lived during the Colonial Period.

The mound lay about 50 meters east of an old Spanish well, still known by the name of San Juan; and this fact, together with its location on what had been the east side of a plaza, the proper position for a Roman Catholic church, indicated that it might be the remains of the former church of San Juan Bautista Yaxacumche.

The excavations disclosed a foundation-mound some 40 meters long, 30 meters wide and 2 meters high, its longitudinal axis east and west, its east, north and west sides faced with four courses of masonry arranged in retreating steps, like the narrow treads of a steep stairway; these treads were about 15 centimeters wide. On the south side they are so much wider (1.5 meter) that it would seem the mound originally faced in this direction.

Traces of a plaster floor could be distinguished here and there, about 30 centimeters above the top of the fourth course of masonry on the east, north and west sides. There was so little débris above this floor-level and what there was contained so few stones, being composed mostly of earth and lime plaster residue, that it was evident there had never been a masonry

super-structure. On the other hand there was sufficient débris to indicate a former super-structure of saplings and thatch, its walls perhaps daubed with mud or lime plaster.

The excavations yielded a considerable quantity of potsherds, but no whole or even restorable pieces. These were examined by Mr. H. B. Roberts, who reports that 80 per cent are of common wares, which throughout the prehistoric and historic periods show no marked change and are therefore of little value for chronologic determinations. The remaining 20 per cent were of a type unknown to him, though he felt that they might be allied to the wares of the Puuc region.

The excavations established that this mound was not the remains of a Roman Catholic Church, but whether it dates from before or after the Conquest could not be settled by the evidence at hand. When the significant 20 per cent of the ceramic remains shall have been identified, its chronologic position will be clearer.

THE ARCHITECTURAL SURVEY

The purposes of the Architectural Survey have been outlined in earlier reports.¹ It was there pointed out that the architecture of the Maya was a highly important part of that culture and as such might be expected to reflect the growth, development and general course of Maya civilization. In its broader aspects, then, the Architectural Survey is to be regarded as a step toward the reconstruction of Maya history. More specifically, its aims are the determination of cultural and ethnic movements and the establishment of time sequences as reflected in architecture.

At the start of operations in 1932, the hill region of Yucatan, known as the Puuc, was selected as the initial point of attack. This was done primarily because of the large aggregation of comparatively well-preserved buildings that occur in the area, and secondarily because of the relative ease of access to these ruins. It was thus believed that at the outset the survey might amass a considerable body of data that should serve as comparative material for further work. While the Puuc ruins were to be the starting point for comparative architectural study, certain other sites in Yucatan that held promise of considerable importance, and thus might be termed strategic in indicating architectural trends, were noted as prospective localities for work in the near future. During that season operations were carried on at the large site of Labna and at several small sites in the Sabacche region of the Puuc, the season being brought to a close with work at the strategic site of Yaxuna in the center of the peninsula.

The Architectural Survey did not enter the field in 1933 but returned to Yucatan late in the autumn of 1934. A continuation of the study of ruins representative of the Puuc region was the main objective, and work at the large sites of Sayil and Kabah occupied the greater part of the season. A certain amount of work was also carried on at the ruins of Holactun in the savanna of Xcalumkin in Campeche, and a brief visit was paid to the Maxcanu region, notably to the ruins of Oxtintok. In addition to the

¹ Year Book No. 30 (1930-31), 117-119; Year Book No. 31 (1931-32), 96-97.

strictly architectural work of the earlier season, the sites of Sayil and Kabah were mapped, a sketch map was made of that part of the Xcalumkin savanna that includes the ruins of Holactun, and observations were taken to determine the geographical coordinates of the sites of Labna, Sayil, Kabah and Holactun.

Reviewing the results of the survey up to the present time, it is felt that certain facts dealing with the environment of the Puuc region, or more precisely the effect of the environment upon the ancient culture, are beginning to be understood. It is, for example, interesting to note that a region which probably harbors more known remains than any other area in Yucatan appears to be the most fertile agricultural region in the peninsula; also that due to an almost complete absence of natural water supply the inhabitants resorted to the artificial storage of rain water in underground cisterns, known as *chultunes*, and that great numbers of specialized, platform-like structures were created for this purpose. Turning to matters pertaining more strictly to building remains, the ruins of Labna, Sayil and Kabah exhibit a certain uniformity of plan in that each possesses an artificial causeway, or *sacbe*, with a general north-south axis and with important buildings or groups of buildings at each terminus. There is, moreover, some reason to believe that intercity causeways may have existed, one connecting Kabah with Uxmal being a distinct possibility.

Construction practises have been studied and thoroughly recorded, and a large amount of decorative detail, both architectural and monumental, has either been discovered or has been recorded for the first time.

In attempting to evaluate the work of the Architectural Survey in Yucatan, it is felt that real progress has been made toward the original objective of collecting a body of architectural data to serve as comparative material for further work. An obvious lacuna in the knowledge of Puuc architecture is found in the absence of an adequate architectural study of the outstandingly important city of Uxmal. It is hoped, however, that this will shortly be filled by publication of the extensive researches made at the site by Tulane University. It is also highly desirable that a rapid reconnaissance be made of a number of lesser sites in the Puuc. All the information thus far collected confirms the previously existing belief that the architecture of the region is remarkably homogeneous. It has thus been extremely difficult to discern architectural trends and developments within the area. Due to the scarcity of superposition of buildings that yield information without resorting to excavations beyond the scope of survey work, it has also been hard to interpret architectural styles in terms of chronology. These difficulties suggest that the survey must pay increasing attention to distribution of architectural types as opposed to stratigraphic sequence at any one site.

The small amount of work that has been carried on outside, or on the borders of, the Puuc has led to rather different results. While there is a wofully small amount of architectural detail preserved at Yaxuna, there is every reason to believe that two types of construction, one of them linked with the Puuc and each representing a different time period, occur there.

Somewhat similar conditions seem to be present at Oxlkintok, judging from a brief inspection of those ruins. The remains at Holactun-Xcalumkin, on the other hand, do not suggest two or more clear-cut periods of occupation, but rather an unbroken development of architectural style that appears closely related to that of the Puuc.

It thus seems that the greatest opportunities for observing architectural development and for arranging architectural styles in time sequences lie outside the Puuc. In spite of that fact it is not believed that the relatively intensive work carried on within the area has been wasted. The homogeneity, possibly even static quality, of Puuc architecture makes it an admirable norm with which other types may be compared. It is probable, moreover, that only through a fairly complete knowledge of this architecture will developments in other regions be intelligible.

CERAMICS—H. B. ROBERTS

The general program of ceramic research in the Maya area has been outlined in previous Year Book reports. In the continuance of this investigation Mr. Roberts spent the period from the middle of November 1934 to June 1935 in the peninsula of Yucatan. The Ceramic Survey was, as in past field seasons, combined with the Architectural Survey under Mr. H. E. D. Pollock. This arrangement has proved mutually beneficial and at the present time is the most satisfactory method of conducting the Architectural and Ceramic Survey of the Maya area. Ceramic studies were carried on at Chichen Itza, Saybil, Kabah and Holactun (Xcalumkin).

The ceramic material from Chichen Itza examined and classified during the past field season consisted of the specimens collected by Mr. John Bolles in the spring of 1934. These potsherds were obtained in the excavation of the East Mound of the Monjas group. This series completes the available ceramic data from the Monjas group. The pottery from the East Mound is generally representative of the period of the Mexican (Nahua) occupation at Chichen Itza and would seem to be typical of the phase nearing the close of that period. In some sections of this unit of the Monjas group, potsherds were obtained which represented wares characteristic of the post-Mexican (Nahua) stage in the history of Chichen Itza—a period identified by the reappearance of pure Yucatecan-Maya forms.

Mr. Roberts also examined the ceramic material collected by Dr. S. G. Morley at Yaxacumche, a site near Okutzcab. The wares from this site are in the main similar to those from the Puuc region. About ten per cent of the rim forms wares are early in the chronological sequence of the pottery of the Puuc. The majority of ceramic specimens from this site are characteristic of the final phases of the historic development in the Puuc. There is an additional ten per cent of the wares from Yaxacumche which can not be identified by the writer at the present time. It is unfortunate that it was impossible to obtain a stratigraphic sequence of the above mentioned wares. The importance of ceramic material from this site can not be over-emphasized as it represents the first definite evidence of the spread of Puuc types beyond the range of hills known by that name in Yucatan. It is hoped that further work may be carried on in this region as it has an important bearing

on the general problem of the first Nahua invasion of the peninsula of Yucatan.

The ceramic survey of the archæological area known as the Puuc was begun in 1932. Mr. Roberts was unable to continue this survey until the past field season when the sites of Sayil and Kabah were investigated. While the sherds obtained in 1935 have not been thoroughly studied and the data compared with those obtained in 1932, the preliminary sorting and classification of the material confirms the evidence obtained from Labna and the other sites investigated in 1932.

The most important information obtained from these two sites was the discovery in the lowest strata of two trenches at Kabah of polychrome sherds of the same general type as those from Holmul V and Uaxactun III. Polychrome sherds of wares assignable to the above two periods have been found under stratigraphic conditions at two other sites in the Yucatan peninsula; namely, Coba and Yaxuna. The Coba and Yaxuna sherds were found in strata which did not contain any of the standard Yucatan-Maya wares. At Kabah the polychrome wares were found in direct association with the earliest of the Puuc wares and rim forms. It is interesting to note that these Petén wares occur at sites at which, with the exception of Coba, no initial series dates have been discovered.

The chronological sequence of rim forms and wares in the Puuc area can now be arranged on the basis of actual stratigraphic evidence. The series begins with a type of pottery which has been identified as the polychrome of Holmul V and Uaxactun III and continues through the Yucatan-Maya wares to and including the introduction of Fine Orange—a ware which was Mexican in origin.

A factor of importance in the final determination of the position of the sites of the Puuc in the history of the Yucatan-Maya is the total absence of Plumbate. This ware has not been found in stratified deposits in any of the Puuc cities.

Since at Holactun (Xcalumkin) there occurs an initial series date, it was hoped that the ceramic material would throw some light on the general problem of the appearance of Petén polychrome wares in Yucatan. Mr. Roberts, however, failed to locate any refuse deposits which yielded this information. The data from this site are at present very perplexing. It was not possible to obtain any definite stratigraphy, but the majority of the rim forms and wares from the lower cuts were typical of the later phases of the Puuc. The mass of the material was similar to that of the Mexican period at Chichen Itza. The Holactun pottery seems to represent a reoccupation of the site at a time post-dating the original construction of the city. Until the sherd series has been more thoroughly studied and further data collected, it is impossible to state the exact position of Holactun in the ceramic history of northern Yucatan.

In addition to the field investigations on the ceramic history of Yucatan, Miss Anna O. Shepard of the Laboratory of Anthropology of Santa Fe, New Mexico, has begun a technological study of the pottery of this area. The Mexican Government has kindly permitted the exportation of the material necessary for this research.

HOUSE-TYPE STUDIES IN GUATEMALA—R. WAUCHOPE

The study of modern Indian house types, initiated in Yucatan and Campeche during the months of February to June 1934, was continued in Guatemala until the middle of August.¹

Houses were investigated in the non-Indian lowland settlements from Puerto Barrios southwest to Quirigua; in the semiarid and semimountainous country from Zacapa south to Chiquimula, San Esteban and Santa Elena, then east to San Juan Ermita and north to Jocotan, near the Honduran border; in the highlands from Guatemala City west to the Lake Atitlan villages, to Quetzaltenango and San Pedro Secatepequez, and northwest to Chichicastenango, Santa Cruz Quiché, Huehuetenango and Chiantla. On the return to Guatemala City two days were spent at Santa Apolonia and Tecpan. A week's stay was made in the Alta Vera Paz at San Juan Chamelco, Coban and San Cristobal, the Baja Vera Paz being observed on the return trip south to San Agustin on the railroad. From Guatemala City the railroad was followed west to Retalhuleu and its neighboring Cakchiquel town, San Sebastian; then northwest to the Mexican border at Ayutla. The final trip was to Cuilapa, southeast of Guatemala City. The Petén had already been visited by Mr. Wauchope in 1932.

Besides making a detailed study of actual house construction, Mr. Wauchope recorded the way in which abandoned houses fell to pieces and what clues to the nature of their perishable superstructures remained on sites where the framings themselves had disappeared. The geographical distribution of variable features, such as ground-plans, was recorded and information as to the relative antiquity of these variations was obtained whenever possible. Word lists of the names of various parts of the houses were collected in Chorti, Quiché, Cakchiquel, Zutugil, Mam, Jacalteca, Kekchi and Pokonchi. Attention was also directed to house furnishings, to surrounding property, and to the social significance of boundary walls and of the allocation of space within the house itself. Any related items of sociological, religious or psychological interest were also noted.

The Guatemalan house was built on the same fundamental structural plan as the Yucatecan house. Practically the only differences between houses of the two areas were minor. In Guatemala, for example, wall plates rested in the forks of the mainposts; in Yucatan they were carried by cross-beams, which rested in the mainpost forks. In Guatemala the pole plate was usually a large and additional member of the house framing, and, distinct from the wall plate, it was carried by cross-beams; in Yucatan the same timber often served in both capacities, or if distinct the wall plate was much smaller and lashed to the under side of the common rafters. Again, Guatemalan main rafters were not always forked like their Yucatecan counterparts, and were footed differently to the nuclear house framing.

The wide-spread use of adobe brick wall masonry and of adobe mud daubed over a cane or light wooden wall framing was another point of difference between the houses of the two countries, for Yucatecan "bush house" walls, with a few exceptions, were built of heavy vertical wall poles, or of light wattle (both horizontal and vertical), or of dry rubble masonry.

¹ The purpose of the house-type survey is explained in Year Book No. 33, pp. 100, 101.

The outstanding difference, however, was that of ground-plan. Guatemalan houses were invariably either square or rectangular, but in Yucatan there were no square houses at all and rectangular houses were distinctly localized in their sparse geographical distribution, being in most cases correlated with non-Indian populations. The characteristic apsidal house of Yucatan was entirely absent in Guatemala.

There was some hearsay evidence in Guatemala that the square house plan and the resulting pyramidal roof were older and possibly more nearly aboriginal forms than the rectangular houses with longer ridgepoles. This evidence was corroborated to a certain degree by a correlation of these forms with those of the more isolated, purer-Indian populations, such as those of Santiago Atitlan, San Pedro de Laguna, San Lucas Toliman, San Sebastian and Santa Apolonia.

Throughout the investigations comparison with or contrast to the ancient house types excavated at Uaxactun, Guatemala, and examined in the environs of Chichen Itza, Yucatan, was kept in mind. Platform substructures, terraces, ground-plans and household furnishings were the outstanding possibilities for this phase of the study.

Data for further investigation of the "temple prototype" theories were collected, this subject to be discussed in full in a forthcoming publication on the season's work.

The word-lists present some interesting subjects in linguistics. The widespread distribution of words having similar literal translations in many languages was significant; "Mouth of the house" for "door," "road of the rat" for "roof purlin," and "leg of the house" for "mainpost" are examples. The almost complete displacement of an aboriginal word for "main rafter" by the Spanish word *tijera* (scissors) or some Indian corruption of this word was wide-spread, not only in Guatemala but in Yucatan also. Mr. Wauchope is at present going through early Indian dictionaries and *Relaciones* in the hope of finding linguistic solutions to some of the historical problems arising from the seasons work. Whether or not, for instance, the rounded ends of Yucatecan houses are aboriginal or are intrusions from another area may be revealed by the finding of a Sixteenth Century Indian word for some part of the house essential to this type of house-plan. Many early Spanish records are also being searched for any references to the Indian dwellings of those times.

Mr. Wauchope hopes that future investigators in the Maya field will help in this survey by observing the native dwellings of any areas unrecorded for house types, with especial reference to substructures, ground-plans and wall construction.

PHYSICAL ANTHROPOLOGY AND HUMAN GEOGRAPHY—MORRIS STEGGERDA

The Department of Genetics has again cooperated with the Division of Historical Research by making it possible for Dr. Steggerda to continue field work in Yucatan.

In his visits to the Peninsula, Dr. Steggerda has been concerned primarily with the growth of children, this investigation forming part of his larger program in the comparative anthropometry of childhood and adolescence.

He has now carried the work at the villages near Chichen Itza to a point where he is able to make the necessary annual measurements in a relatively short time and is consequently free to devote a part of each field season to other somatological problems and to studies of the human ecology of the region. By so doing, Dr. Steggerda has contributed signally to the Division's program by undertaking researches in somatology, agronomy, nutrition and various other aspects of present-day native life, all of which are of great importance for the interpretation of Maya history, but which neither archæologist nor archivist is competent to prosecute.

On the physical side, Dr. Steggerda confirms the opinion of other observers that the Maya are among the shortest of all North and Central American Indians. During the past year it was found that the Maya from the eastern part of Yucatan (Chichimila) are statistically equal in stature to those in the Chichen Itza area. Their heights are 156.62 ± 0.42 cm. for men and 142.85 ± 0.46 cm. for women, as compared with the Chichen males of 155.11 ± 0.40 cm. and females of 142.72 ± 0.42 cm. It is of interest also to find that the Mam and Quiché males measured in Guatemala averaged 154.66 ± 0.47 cm. Dr. Steggerda believes that the natives of Chichimila possess somewhat more Spanish blood than those of the Chichen region, and that those from Chichen are in turn perhaps more mixed than the Quiches of Guatemala. This may account for the differences in stature for the three groups. Possible mingling with other native stocks, environmental conditions and food-supply must, however, all be considered as factors bearing on this problem. During the past five seasons a considerable portion of the state of Yucatan has been examined, with the result that the Indians of the Chichen Itza area are thought to represent as pure a Maya type as can be found in northern Yucatan.

In 1935 there was also opportunity to measure four Maya from Santa Cruz de Bravo. In bodily proportions these Indians conform very closely to the Chichen Itza type. In stature they were equal to the general average from northern Yucatan. Their cephalic index ranged slightly lower. Their teeth were excellent.

In collaboration with Mrs. Steggerda, a paper has been completed on palmar dermatoglyphics, with special reference to the Maya. The palm prints of the Maya are characterized as follows: 1st, a high frequency of the 9.7.5 type of formula; 2d, an unusually vertical general configuration of the palm, as indicated by the proximal terminations of Line A; 3d, the frequent reduction of Line C to a rudimentary and more often a totally absent condition; 4th, the occurrence of a single comparatively low axial triradius; 5th, an unusually low incidence of the hypothenar pattern; 6th, the low incidence of the second and third-interdigital patterns, and 7th, the exceedingly high frequency of the thenar-first interdigital patterns. It is most significant that the Chinese studied by Wilder (1922) conform in every detail except the last to these characteristics. It is only in the low percentage of the thenar-first interdigital pattern that the Chinese, and Mongolians in general, differ significantly from the Maya and other American Indians.

With Dr. T. J. Hill, Professor of Clinical Oral Pathology of Western Reserve University, analysis has been undertaken of the tooth condition of

Maya Indians. Over eleven hundred mouth examinations have been made. Of males whose permanent teeth have erupted, 19.6 per cent have caries to some degree, as compared with 21.7 per cent for females. This means that of the Indians of the Chichen Itza area nearly 80 per cent do not have caries in their permanent teeth. Considering the extent of caries in such persons as have tooth defects, it can be said that the males have on the average 2.8 cavities and the females 5.3. The conditions found in the deciduous teeth are also of interest; as compared with those of the Whites they are remarkably free from caries. The percentages are higher in the deciduous than in the permanent teeth. For comparative material Dr. Steggerda has observations on more than two thousand young Navajos, of whom only 15 per cent of the males and 21.7 per cent of the females had carious permanent teeth. The Dutch White material, which will also serve for comparison, is not yet fully analyzed, but there is every reason to believe that it will not vary greatly from the usual carious condition found among Whites, which is at least four times greater than that found in the above two Indian populations.

The investigation on the food of the Yucatecan Maya is approaching completion. It has been shown that their diet is very rich in carbohydrates and low in proteins. From weights of the foods consumed daily by Maya laborers, it was learned that between 75 and 85 per cent of their diet consists of maize products.

The vital statistics of the village of Pisté, in the immediate vicinity of Chichen Itza, have been gathered over a period of several years. The following is a summary to date. In 1935 there were 415 inhabitants, of which 207 were males and 208 females. In this town, during the last 17 years, the birth rate averaged 60.1 per 1000 and the death rate 31.7 per 1000. Of all the children born in 109 families, 17.2 per cent died under 2 years of age. The sex ratio of the children born was 108.5 males to 100 females. The average number of children per completed family was 6.7, and the interval between the births was 28 months. The average age of the women at the time of marriage is about 15.7 years. However, this figure is not as accurate as it should be, since many of the recorded ages are not official. The average age of mothers at the birth of their first child, based on exact birthdays, is 18.0 years.

From the animal census taken in Pisté during the last three years a number of interesting facts have been learned. For example, in 1933 the ratio of horses to people was 1 horse to 4.7 people; in 1934, 1 to 5.9; and in 1935, 1 to 7.5, indicating a decrease in horses for these three years, whereas the number of cows has considerably increased. For example, in 1933 there was 1 cow to 6.6 people, but in 1935 the number of cows increased to make the ratio 1 to 4.2. If horses are considered a luxury, then Pisté is less wealthy in 1935 than it was in 1933. This may be directly associated with Carnegie Institution's work at Chichen Itza, since little excavation was done in 1934 and 1935, and for this reason the people have shifted toward the raising of cattle. Comparing these figures with statistics from the towns of Chan Kom and Xocenpich, it may be noted that in 1935 both of these towns had more horses per person than did Pisté, and Chan Kom had many more cows than did either Pisté or Xocenpich. The figures are as follows: Chan Kom, 1 cow to 1.4

people; Xocenpich, 1 cow to 3.8 people; Pisté, 1 cow to 4.2 people. From the Pisté records the ratio of pigs to people was 1 to 1.1 in 1933, 1 to 1.2 in 1934, but in 1935 the number of pigs had decreased so as to make the ratio 1 to 10.1 people. The low percentage of pigs was due to hog cholera, since the ratio of pigs to people in Chan Kom and Xocenpich in 1935 was approximately that which was noted for Pisté in 1933 and 1934. Figures have also been gathered as to the ratio of turkeys, chickens, cats, dogs, goats and bee hives to people.

LINGUISTIC INVESTIGATIONS—MANUEL J. ANDRADE

In January 1935 Dr. Andrade initiated a linguistic survey of the Republic of Guatemala. Lest it be not apparent how this undertaking fits into the general plan followed heretofore in his work on the language of the Maya stock, it may be desirable to refer briefly to the purpose which previous field trips were intended to serve.

The aim of the first field trip in 1930 under the auspices of the University of Chicago was to collect the data necessary to describe the aboriginal language of the Indian population of the Peninsula of Yucatan, the language hereafter referred to as "Yucatecan Maya." Being aware of the historical interest connected with the study of this language, immediately after this first research, Dr. Andrade began his study of the Huastec language spoken at present in the northern part of the state of Vera Cruz, and in the adjacent portion of the state of San Luis Potosí. The historical interests alluded to may roughly be specified as follows. Apart from the scientific interests which the description of a language can be expected to serve merely as a collection of facts, a comparative study of cognate languages not infrequently has thrown light on the history of the peoples who speak them. The circumstances that Huastec and Yucatecan Maya are evidently cognate, and that the peoples who speak them have not occupied contiguous geographical regions presumably for more than a millennium, are of the sort which have been particularly advantageous in other fields of historical inquiry. The possibility that such circumstances might be favorable has been realized in part, and, although it is premature to make any pronouncement concerning further developments, it does not seem unlikely that future results may be illuminating. After this initial field research covering a period of seven months, further work on the Huastec language and on dialects closely related to Yucatecan Maya was conducted as a joint project of the Carnegie Institution of Washington and the University of Chicago. Up to this point the accomplishments may be thus summarized: (1) we have material for a detailed description of Yucatecan Maya and Huastec, two divergent members of the Maya linguistic family. (2) This material serves as a convenient yardstick, so to speak, to estimate the structural and phonetic divergences of any language of the Maya family which may be the object of future research. (3) The Huastec material is intended to serve as a point of reference to determine under favorable conditions the relative antiquity of the linguistic facts observable in the present stage of the languages of this family. This third particular has an obvious bearing on historical interests, while the second may or may not have a direct bearing on such interests, depending on the nature of the facts which future research may reveal. The degree of

linguistic divergence among geographically contiguous or remote languages can be indicative of historical events. So far as one may venture a conjecture grounded on the available data, it seems that, with few exceptions, linguistic divergences and geographical proximity or remoteness are roughly proportionate in the Maya area. If future research proves that such is actually the case, the facts may justify at least one historical hypothesis, namely, that it is probable that the peoples who speak the various contiguous and slightly divergent languages and dialects have occupied the same or similar geographical positions with respect to one another for a period of time proportionate to two factors: (a) degree of divergence, and (b) rate of divergence, that is to say, rapid or slow change. The latter factor is of difficult determination at the present stage of our knowledge of linguistic change, but under favorable circumstances and within wide ranges some possibilities may receive more support than others.

With this initial work as a provisional basis, further steps in the Maya linguistic project follow the plan outlined in Year Book No. 30 (1930-31), wherein (p. 128) it was stated that "The plan which seems advisable for future research in Maya linguistics is to complete an intensive study of Huastec, and then to proceed with a general survey of all the other dialects of the Maya family. This survey should include a careful study of the phonology, a collection of extensive vocabularies, sufficient material on grammar to obtain a general idea of the morphology, and some text material. This extensive study will offer suggestions as to the dialects on which further intensive work should be done. The intensive study should be applied to those languages which, from our general survey, may appear to be like points of departure from which a group of dialects may have evolved, or to those, if there be such, which may not naturally fit into any group." Thus, Dr. Andrade's field trip to Guatemala during the period covered by this report conforms with the original plan, although the procedure to which we shall presently refer was suggested by the conditions disclosed in this last field work.

The conditions referred to are as follows. Several Quiché informants from the neighborhood of Chichicastenango asserted that the speech of certain other parts of the Department of Quiché was different from theirs. The differences were characterized (as untutored individuals would generally be expected to do) on the basis of mutual intelligibility, or merely as "different" in various degrees. Thus, they would say, "We can not understand the people of X" or "The people of Y speak in a manner quite different from ours," or "We can communicate with the people of Z, but their speech is peculiar." Now, according to all the linguistic maps available, the people of X, Y and Z are supposed to speak Quiché. There is nothing unusual about this, of course, if we consider that a linguistic map of Europe may represent the Italian peninsula and some of the adjacent and more distant islands as having Italian for their common language, whereas a detailed map may show eight dialectical divisions of Italian and sixteen subdivisions of these eight divisions. However, in view of the fact that the speech of the area labeled "Quiché" on the maps is not uniform, and that the Quiché of some sections is easily intelligible to the Cakchiquel of certain sections but not to others, it

would not be advisable to rely on the linguistic maps without examining the situation more closely. Specific instances are exemplified in the linguistic relations of Chichicastenango, Tecpan and Solola. The peoples of the last two places are supposed to speak Cakchiquel, but, according to all the natives questioned, they can not understand each other's dialects. Whereas the natives of Chichicastenango, who are supposed to speak Quiché, can converse with the natives of Tecpan as easily or, according to some, more easily than with other Quiché peoples. The report that the Quiché of Chichicastenango can communicate in their own dialect with the Cakchiquel of Tecpan was submitted to a test during Dr. Andrade's stay in Chichicastenango, and its accuracy was corroborated in a rather conclusive manner. To what extent all the reports concerning differences and similarities of speech are true, and whether or not such situations obtain throughout the Republic of Guatemala, are the queries which will guide our linguistic research in the immediate future.

The procedure will be as follows: (1) In a given community, A, a number of electric records of free speech will be made, in addition to and as a part of the material referred to in the above quotation of our original plan. As usual, the records are translated as accurately as possible with the aid of individuals of the community A. (2) As many individuals of community A are questioned as to the speech of neighboring communities. If their answers agree concerning the absence of dialectical differences in community B, but there is complete or partial agreement as to the dialectical differences in community C, we proceed to work in C and postpone our investigation in B, or devote sufficient time to it to verify the reports, provided, however, that favorable conditions obtain, such as, for example, the location of B on the road to C. (3) In community C the natives listen to the reproduction of the speech recorded in A, and if they claim to understand it, their translation is compared with that given by the natives of A. In brief, objective data are thus obtained as evidence that the people of C do or do not understand the speech of A, or understand it partially. If they do not understand it, community C is the immediate locus of our further research.

Within the confines of this report, it is not feasible to enumerate the technical advantages which are expected to result from the employment of this procedure in our survey, and the opportunities for the disclosure of information pertinent to the chief goal of the Maya linguistic project. To cite one particular, the survey is expected to give us what we may provisionally call a map of mutual intelligibility. Among the various uses of such a map, it may be pointed out that it can be a valuable aid to the ethnologist, besides providing organized material for a reliable genetic classification of the extant dialects of the linguistic family under consideration. In other words, it can be both an instrument of research and a useful by-product.

In this first field work in Guatemala, Dr. Andrade had opportunity to take notes on the Quiché dialects of Chichicastenango and Totonicapan, on the Jacalteco dialect of Santa Eulalia, and on the Mam of the neighborhood of San Juan Ostuncalco. The chief aim of the trip was to become acquainted with the linguistic situation in Guatemala, although the material collected in Chichicastenango may serve as the first sampling in the survey.

ETHNOLOGICAL AND SOCIOLOGICAL RESEARCH—R. REDFIELD, S. TAX,
A. VILLA

During 1935 the program initiated in Yucatan in 1930 was brought nearer completion, and a new enterprise was initiated in Guatemala.

The Yucatan project calls for the study of four types of communities chosen with reference to the degree to which modern urbanized ways of living have affected the Maya-Spanish folk culture which developed in the rural villages. These four types and the communities chosen to represent them are, in the inverse order of relative isolation: the city (Merida), a railroad town of mixed-blood population with connection on the one hand with the city and on the other with the rural Indian village (Dzitas); a village of Indian agriculturists, independent of hacienda employment and incorporated into the political and educational organization of the state (Chan Kom); and a village of politically independent, on the whole tribally organized Indians in the more remote hinterland of Quintana Roo (Tuzik or X-Mahben).

At the close of 1934, Dr. Asael T. Hansen ceased the work of collecting field data relevant to his study of Merida and returned to the United States. During 1935 he devoted time free to him from other obligations to the writing of a monograph on this urban community. The central problems to which his analysis is devoted are the relation between the culture of the urban masses and that of the privileged classes, the changes in the folk culture as it appears among the urban people, and the trend of change from the older society, involving fixed social classes and the dominance of personal and familial relations, to the newer, more mobile, secular and individualistic mode of living.

The materials which Dr. and Mrs. Redfield collected in Dzitas in 1933 have now been subjected to some study and a beginning made in the writing of a report based upon them.

In the spring of 1935 Dr. Redfield was for five weeks in Yucatan, revisiting Dzitas and securing materials necessary for the completion of the report on that community. He also spent some time in Chan Kom, and collected data on changes which have taken place in that village since his last visit. It has been suggested that a restudy, or repeated restudies of one community already studied, would give a "genetic" account of acculturative change which would be valuable in the further investigation of the characteristics of this kind of social change. The data collected this year can be used to guide the planning of such a restudy of Chan Kom.

Mr. Alfonso Villa continued his studies in anthropology at the University of Chicago until June 1935, when he returned to Yucatan. In August he went into the interior of Quintana Roo and began the study of the community chosen there, for which he had done the work of reconnaissance in 1932 and 1933.

The highlands of Guatemala, preserving the richest survivals of pre-Columbian Maya cultures, besides furnishing material to supplement archaeological work, are exceptionally fertile for social-anthropological research. The highlands, in pre-Conquest days probably marginal to the high civilizations, are today populated by over a million Indians who speak

Maya languages and whose lives are relatively uninfluenced by the outer world.

Studies of these Indians in particular towns have already occupied some ethnologists, but the work now being initiated by the Division represents the first attempt at systematic and comparative research.

Dr. and Mrs. Tax undertook, in November and December of 1934, a preliminary survey of the western part of the highlands; from January to June 1935 they remained in Santo Tomas Chichicasteñango for more intensive work. The program calls for this alternation of systematic survey and intensive study of chosen towns—always with the dual purpose of (1) understanding the general configuration in the light of geography and history; and (2) advancing the solution of sociological problems for which the region appears to furnish crucial data.

The use of comparative methods, toward the latter end, is much facilitated by the division of the population into easily defined units. Due probably to the irregular topography, the people, in dialect and culture, are split into a large number of small territorial groups. Each political *departamento* is divided into *municipios*, each of which is typically homogeneous in language and culture and all of which differ from one another in varying degrees. The *municipios* are effective social segments, each tending to be specialized economically, to have its own social and religious system, its own distinguishing costume, its own dialect; each has, in addition, a strong feeling of unity and a desire to be endogamous.

In addition to the graduated cultural differences that one expects to find between contiguous ethnic groups, there are in these highlands a number of startling and fundamental, even though sporadic, variations between *municipios*. These variations, which as additions to normal differentiae imbue the region with its extraordinary sociological significance, may be classified roughly into geographical, racial and historical.

The geographic differences revolve about the fact that there are, in general, three types of *municipios*. One consists of a town—which may be simply an economic and religious center unpopulated except on certain occasions—and surrounding country in which the people live on their scattered farms. A second type is like the first except that there are one or more smaller villages in addition to and dependent upon the town. In the third type all or most of the people live permanently in the town and leave it when necessary, for short periods, to work the surrounding fields.

The presence of two wide-spread racial groups brings about the second group of differences. Living side by side with the relatively pure Indians are the *ladinos*, who represent an old mixture of Indian and Spanish. These racial groups are sociologically important because they are at the same time economic and social classes, and in some respects almost castes. Variations occur both in the distribution and position of these classes. There are *municipios* containing solely Indians and others with a high percentage of both Indians and *ladinos*. There are *municipios* in which even the small group of *ladinos* are politically dominant, and others in which the Indians share municipal responsibilities. Furthermore, there are towns in which

the *ladinos* form a bourgeois class and others where, like the Indians, they work their own farms and do their own chores.

Variations derived from historical accidents are less easily cataloged. First of all, the superimposition of Spanish culture (and Christianity)—especially since the Indian cultures were undoubtedly already different—could not have been uniform on all the groups, and the cultures today do not contain the same amount or kind of Spanish admixture. More recent contacts and changes are no more uniform: the introduction of commercial planting, drawing some Indians to new occupations, has affected some *municipios* greatly and some hardly at all; intermarriage between modern Europeans and the Indians, in some cases giving rise to new social classes, has occurred in important proportions in only one region; the recent introduction of foreign goods, as well as Protestantism, has had unequal effects in different parts; military service has made inroads in some *municipios* and none at all on their neighbors; and the program of Indian education, successful in some *municipios*, has yet to be felt in others.

These differences are largely independent, and cut across one another; but since at the same time the *municipios* are brought together in a network of trade relations and exist under a common government and its political and economic system, the varieties must be studied in their common cultural matrix. Such problems, therefore, as the interrelations of geography, history, and culture, the formation of classes and castes, the influences of one culture on another, the differential effects on individuals of slightly differing social frameworks—for all of which the highlands furnish pertinent data—require here the combination of survey and intensive study planned.

Chichicastenango, the object of the first intensive study, illustrates a particular type of *municipio*: so large that personal relations can not be established among more than a fraction of the people; with a town occupied chiefly by bourgeois *ladinos*, the Indians living scattered through the countryside most of the time; the idea of property strong, competition keen, and many Indians landless; with Indian self-government, but subordinate to *ladino* officials. Since they enter as factors in the distinctive customs, local politics and social relations in Chichicastenango, it may be presumed that were even one of these features different, the tenor of the whole culture would correspondingly be altered. It therefore now becomes desirable to study a community radically different.

A preliminary survey has suggested that some of the *municipios* on the shores of Lake Atitlan, hardly ten miles from Chichicastenango as the crow flies, are dissimilar to Chichicastenango in almost every factor mentioned above. Intensive work in one of them may demonstrate the limits of the effects of such factors, as constituting the general social framework, on culture. Meanwhile, further survey work should point out: first, types of variation between these extremes; second, strategic locations for further concentrated research. It is planned during 1936 to conduct this survey as a joint enterprise with that of the Linguistic Project under Dr. M. J. Andrade.

AGRONOMIC INVESTIGATIONS IN YUCATAN—R. A. EMERSON,
J. H. KEMPTON

Studies of modern Maya diet made by Dr. Steggerda, Dr. Redfield and Dr. Rollin Atwood indicate that maize forms some 85 per cent of all food consumed. And, as would naturally be expected, the whole existence of the Maya is conditioned by the cultivation of this plant. There is also every reason to suppose that it played a rôle of equal, or even greater, significance in pre-Columbian times. Understanding of the present and interpretation of the events of the past therefore depends very largely upon knowledge of maize-growing methods and of the potentialities of the area for maize production.

The Maya of Yucatan cultivate maize by the so-called milpa system, under which an area of forest sufficient for the farmer's needs is felled at the beginning of the dry season. Toward the end of the dry season the desiccated slash is burned, and when the rains come the seed is planted. If all goes well, the first year's crop will be a good one; in the second year the return will be less. Further consecutive sowing of the same field is seldom attempted; it is allowed to revert to bush and a new patch is cleared. This type of farming obviously requires a great deal of land, because the old milpa is not used again until forest conditions have become reestablished. As this is a slow process, a large percentage of all available ground must at any given time be lying fallow.

One of the most vitally important of problems of Maya archæology is whether the milpa system was followed by the prehistoric people of northern Yucatan and of the Petén, or whether some form of intensive agriculture was practised. Upon its solution depends judgment as to the size and distribution of population, as to ancient economic and social systems, and as to the causes for the decline of the Old Empire. But until we know much more about the working of the present-day milpa system, we can not hope to do more than guess regarding its antiquity, nor more than speculate as to what its effect would have been upon the former life of the Maya. For this reason the agronomic survey was inaugurated. The field work of 1935 was done by Professor R. A. Emerson of Cornell University, and J. H. Kempton of the U. S. Dept. of Agriculture. Most valuable assistance was rendered by Dr. Morris Steggerda, who made available the data and experience obtained in his thorough studies of the villagers of Pisté. The method followed in the investigation was that of interrogating the Indians in their milpas where their answers could be weighted by the observer's judgment. The area visited was limited largely to the State of Yucatan, though a brief trip was made to the region centering on the City of Campeche. The milpas studied were cultivated by the villagers of Pisté, Xochenpich, Oxkutzcab, Ekhum, Aquil, Teabo, Tecax, Peto, Sabaquil, Campeche and Uayamon.

With the exception of the fertile belt extending from Ticul to Peto, on both sides of the hills, estimated yields are remarkably uniform, falling within the range of one to one-and-a-half cargas per mecate (83 bushels per acre), for the first crop following the burning of the bush, and approximately one-half to three-quarters of the first year yields in the second season, after

which time the land is abandoned to bush. In the poorer regions east of Chichen Itza these estimates are halved for both years, and in the fertile hill country they are doubled or even tripled.

Although these are merely estimates, they are far from unsupported guesses. Doctor Steggerda's studies show a remarkably uniform consumption of 1.6 pounds of corn per adult per day. For the standard family of two adults and three minor children the annual consumption of corn, therefore, is about 45 bushels. To produce this amount of corn with a yield of one carga per mecate requires between three and four acres, which is the amount of land most of the Indians claimed to farm. Estimates of acreage can be made more accurately than estimates of yields, and the actual size of the milpas could not have differed greatly from the given size without detection. Further corroboration of the estimated yields is found in the estimated acreages in the fertile hill region where the number of mecates in a family milpa is about half that in the vicinity of Chichen Itza.

There is no question about the decline in yield of the crop grown the second year following the burning of the bush. Some ascribe the drop in production to loss of soil fertility, others think the difference is due to the small quantity of ashes from second year burns and still others blame the weeds. From field observations the latter explanation seems the most important, though undoubtedly all three are operative. With one or two minor exceptions there was no difficulty in determining from mere inspection of the weeds and returning bush whether a given milpa was in its first or second year.

In the second-year milpas the general practise is to cut weeds twice or even three times, and when it is understood that it takes more time to weed a mecate of land than it does to fell the bush one wonders why a second crop is ever attempted. Possibly in the days of stone axes, cutting new bush was more of a task than now and the practise of growing two crops has persisted from ancient times.

In the fertile lands milpas are weeded every month during the growing season. The necessity for this frequent weeding limits the grower to an acreage not more than one-half to one-third that planted elsewhere in Yucatan, but the Indians believe that the high yields compensate them for the smaller acreage. Actually, in corn production per man the fertile region enjoys no advantage over the Chichen Itza area. If anything, the man hours required per unit of corn are slightly greater in the fertile regions.

Following the second crop, milpas are abandoned to return to bush. Estimates as to how many years are required before the second growth of bush is large enough to burn are very unsatisfactory and those estimates can not readily be checked. The estimates range from 8 to 18 years with most replies centering around 8 to 10 years. The actual time required for the bush to regain burning size should be determined, as this period constitutes the greatest unknown factor in calculating the population a given region is capable of supporting.

At none of the places visited either in Yucatan or Campeche does grass seem to be a factor in corn production nor in the reestablishment of the bush. A few acres of grass were found, but these had been planted for pasturage.

No milpas were seen that indicated savannas would replace the bush after corn cultivation had been abandoned. Neither does it seem likely that soil erosion is of any importance in the agriculture of Yucatan or Campeche.

No evidence of destructive bush fires that might result in deforestation and subsequent denudation of large areas was found. So far as the observations of this survey go, the bush seems to reenter abandoned land rapidly whether such land be small clearings surrounded by mature and seedling bush or whether it be large sisal plantations kept cleared for several years. The recovery of the bush, therefore, would seem to be assured under the agricultural practises followed at the present time. Whether or not this conclusion would hold under more extensive occupation of the land is a matter for investigation.

If the bush can be cut every 8 or 10 years following two years in corn and the land produce grain at the rates indicated, there seems to be no reason why this type of agriculture can not continue indefinitely. Even though the time required for the bush to attain cutting size be increased to 20 years, the land seems capable of supporting a population (at its present level of subsistence) of approximately 50 persons per square mile employed in agriculture and an additional 10 persons who may reside in urban communities and engage in non-agricultural activities.

The State of Yucatan produces the maize support for the city population of Merida and Progreso and for much of the labor used on the henequin plantations. It is evident, therefore, that in normal years the present agricultural population, using the methods of culture presumably practised by their temple-building forbears and improved merely by the substitution of simple metal tools for those of stone, is capable of supporting a large non-agricultural society. Yet the most striking thing about the Yucatan bush is the sparseness of the population and the low percentage of potentially productive land actually utilized for growing food. Given a strong administrative control, the present agricultural population could be forced to double its grain output, thus making possible the food requirements of a non-productive population four or five times that of the present urban one.

Present practise gives a marketable surplus over the requirements of the producer of approximately 20 per cent of the crop. If the production per man were doubled by increasing the area cultivated and by intensive destruction of weeds, at least four times as much corn would be available for market as is now the case. If the grain output is doubled by doubling the agricultural population, then the non-producing population could only be doubled also since the ratio of grain consumed to that marketed would remain the same.

Probably in ancient times the production per man was greater and the agricultural population was larger than at present. Thus it seems safe to conclude that in the past the agricultural population was large enough to insure the food requirements of a non-agricultural group (priest, warrior, artisan or noble), larger than the present urban population of the state.

No evidence has been discovered of any form of intensive agriculture, other than the modern fruit tree cultures in the hill region. Indeed, the topography

and rock outcrop is such that intensive agriculture in any form now known is out of the question.

In a general way the agriculture of the present differs from that of the past in two particulars. The introduction of domestic farm animals has forced the Indian to fence his crop as a protection against the depredation of these beasts. Although the fences are not examples of geometrical precision, they do represent much labor and the withdrawal of an appreciable amount of small bush from the burn. The investment of labor in these fences may well be a contributing factor in the use of milpas for a second year, despite the fact that it would require less total hours of labor to burn new bush each year. On the other hand the animals encourage farming at greater distances from the villages in two ways. First they provide easy transportation of the harvest to the village home and second, since most of the animals are kept around the village, the remote milpas often need not be fenced. In the agricultural economy the introduction of the beasts of burden probably represents a loss of efficiency since they could not be used (because of the nature of the terrain) in the actual production of crops, but merely in transportation. It is doubtful whether in view of their food requirements they transport enough more than a man carries to represent a real saving of food. They must, therefore, be considered merely as a social improvement and an agricultural retrogression. Without them the farmer would bear more burdens, but would save labor in corn production.

The second difference of present-day agriculture over that of the past is the disappearance of cotton and to some extent tobacco as cultivated crops. Cotton culture has been completely abandoned and tobacco is a rarity. Probably the latter crop was never as extensively grown as cotton. Cotton, on the other hand, is a necessary now purchased with maize.

Just how much land and time was devoted to cotton by the ancient Maya can not now be determined. If this product did not enter extensively into interregional trade but was used solely to clothe the resident population, probably less than 5 per cent of the land in crops was utilized in growing cotton. On the other hand, if owing to its ready portability and high value as a finished product it served as an article of barter, much more land could have been given over to its cultivation. Land and time so used would have to be subtracted from that allotted to the production of food for the non-agricultural population.

So far as this preliminary survey can be considered trustworthy, the following conclusions are suggested:

(1) The milpa system is the only one practicable in Yucatan even with modern tools and farm animals and there is no evidence that the milpa system as followed with 2 years in maize to 8 or 10 in bush could not continue indefinitely.

(2) So far as the limits imposed by the bush alone are concerned this region can support 50 persons per square mile, together with 10 non-agricultural inhabitants concentrated in cities.

(3) Maize culture has entirely supplanted that of cotton, though beans and squash are usually interplanted with maize and a small amount of tobacco is produced in certain regions.

(4) The crops no longer grown are purchased with maize, so that the cultivated area required by each family has not been greatly altered.

(5) These conclusions are subject to large errors, since there is no definite record of the rapidity with which the bush regains burning size, nor have we any certain information on the yields obtained when the bush is cut the second time. It is possible, therefore, that the number of years which must elapse following a corn crop before the bush can be burned again is much greater than ten or twelve. In evaluating these conclusions it should be kept in mind that they represent the digest of information collected on a trip of only one month's duration. They are, therefore, something in the nature of opinions that must await careful investigation for their ultimate verification or disproof.

SOUTHWESTERN RESEARCH

No field work was carried on during the period under review, as Mr. Morris has been occupied in preparing a definitive publication upon the excavations which, for many years, he has conducted in the La Plata drainage of northwestern New Mexico and southwestern Colorado. This area contains great numbers of ruins, dating from the earliest pottery-making horizons to the close of the Great Pueblo Period. An unusual opportunity is thus afforded for tracing, within the limits of a single ecological province, a long development in ceramic practise. Furthermore, the La Plata region, being contiguous to such other populous aboriginal centers as the Mesa Verde, Chaco Canyon and the eastern slopes of the Chuska Mountains, produces archaeological materials useful for correlating, both culturally and chronologically, various other San Juan groups. Mr. Morris, it may be remarked, was one of the first to appreciate the great historical value of dendro-chronology. He has secured, from the La Plata and elsewhere, a large proportion of the prehistoric beam-specimens used by A. E. Douglass in formulating his tree-ring chronology.

The Chairman has continued study of the collections from the Pecos ruin in north-central New Mexico. A final volume upon the pottery of that site is now in press. In this work he has had the collaboration of Miss Anna Shepard, ceramic technologist of the Laboratory of Anthropology. Miss Shepard has also worked upon Mr. Morris's materials and upon those of Mr. Roberts from Yucatan. In the case of the Pecos wares, Miss Shepard, by petrographic analysis of minerals used for tempering the paste, has been able to show that unexpectedly large numbers of vessels were imported, and to locate the regions from which they emanated. Such findings are obviously important. Their significance, however, lies not so much in direct contribution to the solution of the problems of Pecos, as in indicating that exact scientific methods can successfully be applied to ceramic research.

Under grants from Carnegie Corporation, administered by the Division of Historical Research, Dr. Warren Shepard of Santa Fe and Mr. K. M. Chapman of the Laboratory of Anthropology have been carrying on investigations in the field of southwestern ceramics. Dr. Shepard is making a study of the methods used by modern potters, with a view to determining the

causes of certain defects which injure the sale of Pueblo vessels. Mr. Chapman has completed a monograph upon the decoration of Santo Domingo wares. This will go to press, as a contribution from the Laboratory of Anthropology, in the autumn of 1935.

SECTION OF UNITED STATES HISTORY

The work of the members of the Section is set forth below. The correspondence and editorial work, together with the preparation and publication of the annual list of doctoral dissertations in history, have been carried on by Miss Cornelia M. Pierce, secretary, and Mrs. W. H. Harrison, editorial assistant. The Section is greatly indebted for valuable advice and suggestions to Dr. J. Franklin Jameson and to Dr. Waldo G. Leland.

At the time the last annual report was written it was expected that within a year volume VIII of Dr. Edmund C. Burnett's *Letters of Members of the Continental Congress* would be coming from the press. That accomplishment, however, has proved to be beyond the power of the editor to perform. The preparation of the volume has, for one thing, been protracted by the examination of some newly discovered or hitherto inaccessible materials, among them the John Gray Blount papers recently acquired by the North Carolina Historical Commission. While gleanings from this extensive body of manuscripts were not large, they were nevertheless well worth obtaining. Accordingly there yet remain several weeks' work to be done on the volume before it will be ready for the printer; but, without venturing a more definite prediction, it is hoped that the volume will be off the press by the end of this year.

Volume IV of Dr. Leo F. Stock's *Proceedings and Debates of the British Parliaments respecting North America* is virtually completed and will be ready for the printer in early autumn. The period covered by this volume is that of the Seventh and Eighth Parliaments of Great Britain (Jan. 23, 1727/8—Apr. 25, 1741) and the corresponding period of the Parliament of Ireland. These were active years in the number and variety of American matters which came before Parliament.

First of all, a comprehensive and detailed view of the state of the colonies for this period is given in the frequent reports presented to Parliament by the Board of Trade. The information there contained makes for a better understanding of Parliament's concern in the several questions which came before it, and of the ensuing legislation.

In its far-reaching effects, no act was passed of greater importance than the Sugar Act of 1733. For three sessions Parliament wrestled with the problem. England and France had agreed to abstain from trading with each other's possessions in America. But the northern colonies felt that their economic life was dependent upon free trade with the French West Indies, where rum and molasses were abundant and cheap, and where was to be found an outlet for the surplus provisions, etc., of New England, New York and Pennsylvania. The British West India interests, maintaining a powerful lobby in England, carried their case first to the Board of Trade. Protective measures, also, were passed by some of the island assemblies, the Privy

Council heard petitions on the subject, and finally application for relief on the part of the sugar colonies was made to Parliament. The bill was stubbornly fought at every step. Reports of all kinds, a voluminous pamphlet literature, activities of colonial agents and their counsel, numerous hearings—all figured in the controversy.

The second question which consumed much of the time given by Parliament to colonial consideration was that of the so-called "Spanish depredations." In Spanish-American waters *guarda-costas* were molesting English and American shipping in violation of treaty agreements. Hundreds of papers by way of evidence were laid before both houses; petitions, addresses and long debates make up the record of this controversy which eventually led to war.

Georgia came into being during this period. Its affairs were frequently before the House of Commons. The *Diary* of the Earl of Egmont, a trustee and councillor of the new colony, has furnished much valuable material to illuminate these proceedings.

The volume will present proceedings and debates on a variety of other topics; the Danson case, involving title to shares in Carolina originally held by the Earl of Clarendon and Sir William Berkeley, the disposition of which removed one of the difficulties which stood in the way of ceding the province to the crown; affairs of the Royal African Company; the colonial currency question; the production of naval stores in the colonies; the efforts made to encourage the manufacture of iron; permission to carry rice from South Carolina directly to Europe; an act facilitating the collection of debts in America; and the customary money-bills levying duties on colonial products. There are, finally, many acts, the violation of which carried penalties of transportation.

The printed materials drawn upon for the text of this volume are taken largely from the *Journals*, the reports to be found in Cobbett, Chandler, Torbuck, Boyer's *Political State of Great Britain*, the *Historical Register*, the *Gentlemen's Magazine*, and the *London Magazine*. The Manuscripts of the House of Lords, Additional Manuscripts in the British Museum, and some reports from the French archives furnish the manuscript material.

Dr. Stock has selected and transcribed the greater part of the material to be used for the remainder of his series. Some of this has been partly annotated. It is expected that subsequent volumes will appear more rapidly.

During the past year Dr. Charles O. Paullin has continued his investigation of "Eminent Americans," which is based upon the sketches in the *Dictionary of American Biography*, and at the time of the present writing (June 1935) has completed the abstracting of the information from more than half the volumes of the series. In this statistical analysis the classification of materials is of fundamental importance. Some of its sub-classes are exceedingly numerous, those under "age" numbering more than seventy. Statistics for three of the basic classes for half of the volumes are in the following arrangement. Total number of characters, 6807: distribution by sex, men 6483, women 324; by races, whites 6740, negroes 35, Indians 29, Chinese 2, Hawaiian 1; by degree of eminency, Class A (highest) 48, B 109, C 453,

D 6197. A special study has been made of one of the characters of Class A, Mark Twain, whose centenary occurs in 1935. Through visits to several county archives in Virginia and correspondence with county officials in other states and with Twain's daughter, Mrs. Clara Clemens Gabrilówitzsch of Detroit, Michigan, considerable information was obtained, which is to be published in the *William and Mary Quarterly* for July, under the title "Mark Twain's Virginia Kin."

Acting on a suggestion of Dr. Victor S. Clark, formerly of the Carnegie Institution, that, in view of the enlargement of the Library of Congress by the construction of the Library Annex, a paper on the history of the site of the library should be written while the materials for it were available, Dr. Paullin has given a few odd moments to this subject and has, incidentally, assembled some hitherto unknown facts respecting Abraham Lincoln. It was on this site that Lincoln once lived, as well as his biographer, John G. Nicolay, and the father and uncle of Daniel Chester French, the sculptor of the statue in the Lincoln Memorial, whose widow, Mrs. Mary French, has supplied some valuable information. Of considerable interest was the discovery that after the burning of the Capitol by the British in 1814 the Supreme Court did not meet in the historic Caldwell House, which has long been accepted as one of its meeting places by historians of the court and of the capital city.

The fourth volume of *Documents Illustrative of the History of the Slave Trade to America* by Miss Elizabeth Donnan of Wellesley College, was published in March 1935. The volume concludes the series, which deals with the traffic in slaves from the time when it became a part of European commerce in 1441 until it was outlawed by English and American legislation in 1807. The first two volumes carry the account from the Fifteenth through the Eighteenth Century; the last two emphasize the trade in its relation to the individual colonies.

Mr. David M. Matteson has continued during the year with the Section in his capacity as indexer. Besides making the General Index, which will be published in July 1935, to the six volumes of the *Correspondence of Andrew Jackson* he has proceeded with the index to the *Calendar of Manuscripts in Paris for the History of the Mississippi Valley*. Mr. Matteson has made progress in the general index to the first twenty-five volumes of the *Writings on American History*, the early issues of which were originally published by the Division and later sustained by the American Historical Association. Mr. Matteson's general index to the third series of the *Proceedings of the Massachusetts Historical Society* will probably be published next year.

In November 1934, Dr. James J. Hayden of the faculty of the Catholic University Law School began the task of completing the final volumes on *Judicial Cases concerning American Slavery and the Negro*, which were left unfinished at the death of Mrs. Helen Tunnicliff Catterall. Dr. Hayden is a member of the bar of the District of Columbia and of Maryland. Cases from the states of New York, New Jersey, Rhode Island, New Hampshire, Maine, Massachusetts and Maryland, illustrating the social and economic history of negro slavery, have been prepared for publication and it is ex-

pected that volumes IV and V will be published in the near future. Dr. J. Franklin Jameson has given much time toward the completion of this series.

HISTORY OF YUCATAN PROJECT—F. V. SCHOLES

During the year 1934-35 considerable progress has been made on the following special studies on the history of Yucatan since the Spanish Conquest: (1) The life of Francisco de Montejo, Adelantado of Yucatan; (2) estimates of the population of Yucatan during the colonial period; (3) the beginnings of the *encomienda*; (4) the history of the *cacicazgo* of Acalan-Tixchel, 1526-1612; (5) Landa and the *auto de fé* of 1562; and (6) problems of Indian labor, especially during the decade of the 1570's.

Francisco de Montejo deserves to rank with the half-dozen greatest captains in the conquest of Spanish North America. His sphere of action was not limited to Yucatan and Mexico. During the years 1536-39 he served as governor of Honduras, and he was recalled to activity in that area in the 1540's after the death of Alvarado. It was his ambition to govern a vast area stretching from Copilco to the Rio de Ulua, and by a *cédula* of 1533 he was actually given authority over this entire region which comprises a large part of the Maya area. The forces of nature, reverses of various kinds, the rivalry of Alvarado, and the ultimate restriction of his authority by the Crown made it impossible, however, for him to assert control over this huge principality. Montejo was an enlightened administrator of the Cortés type, and his government of Honduras, especially his policy regarding the Indians, is a bright spot in an otherwise sordid story. Mr. Chamberlain hopes to have his biography completed in 1936.

The remaining five studies listed above are being prepared by Mr. Scholes. The nature of the manuscript sources makes it possible, in fact necessary for the sake of efficient use of the documents, to carry on the several investigations at the same time. Estimates of population, especially during the Sixteenth and Seventeenth Centuries, must be based in part on the levy of tribute, and inasmuch as more than 90 per cent of the villages of Yucatan were held in *encomienda*, the close relationship between the problems of population and *encomienda* is obvious. We have tribute rolls and, in some cases, rough census reports at conveniently placed intervals—1549, 1606, 1689, 1789. Supplementary partial reports are available for some of the intervening periods. Students of archaeology often postulate a dense population for Yucatan in ancient times. During the period since the Spanish Conquest, however, the population has never been large. In 1549 the number of tribute payers was probably between fifty-seven and sixty thousand. Estimates of fifty thousand tribute payers are found for later years of the Sixteenth Century. In 1789 the population of Yucatan and Tabasco was reported to be 364,621, classified as follows: Spanish and mestizos, 54,465; Indians, 264,955; negros and mulattos, 45,201. The population of Tabasco was 30,640.

The history of the *encomienda* requires a preliminary statistical study of the individual holdings and a detailed list of villages, the amount of tribute paid by each, and the *encomenderos* to whom the payments were made is

being prepared. This list used in connection with the documents on the tenure and transfer of land in the notary records in Merida will provide a working basis for the formulation of valid conclusions on the moot question of the relation of the *encomienda* to the development of the *hacienda* system in Yucatan.

The monograph on the *cacicazgo* of Acalan-Tixchel will clear up certain phases of the history of the region south, east and northeast of the Laguna de Términos. At the time of the Conquest the *cacicazgo* of Acalan (the town of Acalan being the same as Izancanac) was an area close to the Laguna de Términos. After the Conquest some of the Indians were moved to Tixchel between the *laguna* and Champoton, and the government of this pueblo was taken over by Pablo Paxbolon, descendant of the *caciques* of Acalan. The later history of the Tixchel area deals mostly with the services of Paxbolon and of Francisco and Martin Maldonado, his son-in-law and grandson, in the conversion and reduction of Indians in the interior of southern Yucatan. The story as told in a series of detailed reports raises one interesting problem. A *probanza* of the services of Paxbolon and his ancestors is given in an Indian language, said to be Chontal. This confirms the statement in the Ponce *relación* that the Indians of Tixchel spoke Putunthan, or Chontal.¹ The modern Chontal area, however, is usually located west of the Laguna de Términos. It is proposed to publish facsimiles of the Chontal text and a transcription of the Spanish translation which accompanies it, with a minimum of comment so that linguists may have this important document available for study. The remainder of the monograph will deal with post-Conquest problems.

The *auto de fé* of Mani of 1562 and the problem of personal service in the 1570's relate to the most important phases of the career of Bishop Diego de Landa. The account of the Mani affair which will be based on the reports and investigations of Landa and Bishop Toral and on the *residencia* of Diego de Quijada, the *alcalde mayor*, will present the first thorough discussion of this most famous incident in the history of Yucatan in the second half of the Sixteenth Century. The controversy over personal service involved Landa because of his active support of Francisco Palomino, the defender of the Indians, who denounced the exploitation of the Indians by the *encomenderos*. Discussion of the problem is necessary, not only in fairness to Landa whose reputation has suffered because of the Mani incident, but also as an introduction to one of the ever-present problems of colonial administration in Yucatan—the problem of Indian labor.

Mr. Lewis Hanke, instructor in Harvard University, has a temporary part-time appointment under the Division for the purpose of continuing his studies in the juristic and theoretical phases of Spanish Indian policy in the Sixteenth Century. A grant from a research fund administered by Harvard

¹ "A little more than fourteen leagues farther toward Mexico, on the same sea-coast, is another town called *Tixchel* of Indians better-looking and a little more polished and diligent than the Maya, who speak a different language called *Putunthan*, by another name *Chontal*, although, in many words it agrees with Maya, and so knowing the one the other is easily understood." *Frays Alonso Ponce in Yucatan*, translated and annotated by Ernest Noyes (New Orleans, 1932), *Middle American Research Series*, Publication No. 4, "Middle American Papers," p. 347.

University has made it possible for him to spend the summer in South America searching for unpublished materials relating to the subject of his investigations.

STUDY OF MAYA COLONIAL DOCUMENTS—R. L. ROYS

Following the consideration of family documents and related papers,¹ a study has been made of various collections of Maya land documents, particularly the *Crónica de Calkini*, *Documentos de Tierras de Sotuta* and *Títulos de Ebtun*. These, together with portions of the Pech and Xiu papers, constitute a documentary history of Indian land tenure from the native point of view during the colonial period.

In the winter and spring of 1935 a trip was made to Yucatan to locate and map the places cited in these papers and continue the task of tracing the frontiers of the former native states. Observations of the country, especially of the location of the more fertile areas, the watering places and evidences of pre-Conquest occupation aided in the understanding of the documents.

The purpose of this research is the application of Maya literature and the documentary sources written in that language to the history of the Yucatecan Maya. The method pursued is the comparative study of this material and its presentation in as adequate form as possible.

Colonial Maya documents contain much concerning the pre-Conquest Maya. They also bridge the gap between modern ethnological studies and the pre-Conquest data, much of which is still in a disordered state. In Maya literature, besides the chronicles and historical narratives there is a wealth of historical allusion in the prophecies, since it was believed that what occurred in a certain katun would recur in another katun of the same name and number. We have still to place many of these events chronologically and to coordinate them.

This, we believe, can be done by further documentary studies with the necessary aid of archaeology (especially ceramic sequences and architectural comparisons), ethnology and economics. The importance of the first seems axiomatic. That of economics has long been recognized in theory; but it is doubtful if the incompleteness of our knowledge was fully realized prior to recent ethnological and agricultural studies.

The importance of the social and political background of hereditary rank also seems obvious. One land agreement even states that "it is in order that our nobles may sustain themselves in time to come." Besides the "Indian *hidalgos*" and "native lords" recognized by Spanish law, we now find mentioned in the Maya documents other nobles, who did not enjoy this distinction. Most of these were local authorities, but the noble Dzul family who lived at Chichen Itza at the beginning of the Nineteenth Century were, so far as we can learn, neither "*hidalgos*" nor officials.

Philosophical historians are turning to Maya history for analogies to support their conclusions as to the causes of the origin, growth and decline of civilizations. Such analogies, in a sphere so far removed from the currents of activity which swept over the Old World, should, when valid, go far to

¹Year Book No. 33.

confirm a fundamental similarity in the development of peoples. The question arises whether the comparisons undertaken do not assume a certainty regarding Maya history which we do not as yet possess. Many facts are recorded, the sequence of which is insufficiently established, and their critical examination continues to be an important task.

Perhaps the best exposition of this aspect of the situation would be a concrete illustration. In the past, misleading analogies have been drawn from Old World history, but it must be admitted that our documentary material for Yucatecan Maya history appears to lend itself readily to one of the formulæ of an eminent philosophical historian.¹

The Spaniards found a "composite society" fundamentally Maya but modified by Mexican ideas. This "affiliated civilization" might be traced as arising from the penetration of northern Yucatan, already an "outlying province" of the "apparented" Old Empire civilization, in the Tenth Century by intruders (an "external proletariat"?), who were the bearers of a Nahuatl culture and became the "dominant minority" in their new home. The result was a brilliant hybrid civilization. Late in the Twelfth Century occurred the "time of troubles" (a definite stage in the history of a civilization), during which Chichen Itza was conquered by Mayapan. The "time of troubles" was succeeded by a "universal empire" (another normal development), in this case the domination by Mayapan of the entire north, which finally ended in a revolution about 1450; and the country broke up into a number of warring independent states. The decline in civilization, which had already set in during the hegemony of Mayapan, became even more marked in the period which followed, and the conditions prescribed by the formula were not lacking. The "dominant minority," which was the repository of the culture, was separated from the "internal proletariat" by tradition and religious cult (the worship of Kukulcan), in which the latter did not share.

However, as we have already noted, our organized material is somewhat scanty and such an interpretation may be invalidated by new data and a coordination of the many uncorrelated facts which we already possess.

Maya culture did not cease with the Spanish Conquest, in spite of the important changes which ensued. Territorial government and religion were the institutions most rapidly affected, but an unconscious recognition of the old frontiers still exists and the modern ethnologist finds religious survivals today. The persistence of the Maya language, even among a large mestizo class, is very significant historically. The Indians were many and the Spaniards were few. Local government, even under Spanish supervision, continued in the hands of the Indians. Changes due to importations of European material culture came slowly; and agriculture, on the whole, still remains very much what it always was.

Any emphasis on the importance of the Colonial Maya documents as a connecting link between the present and the more remote past should not obscure their value as a historical source for the period they actually cover. Even the most indispensable Spanish documents were, after all, written from the

¹ A. Toynbee, *A Study of History*. In what follows we have departed somewhat from Professor Toynbee's application of his formula to Maya history.

standpoint of our own European culture. Those written by the Indians in their own language show the native reaction to European ideas and institutions.

Maya documents of the Colonial period might be roughly divided into two classes. Those cited above are chiefly concerned with the relations of the Indians with one another. The much larger body of Maya texts discovered in the Seville archives by Mr. Scholes appear to deal with the relations between Indians and Spaniards. Both classes furnish much information about the Indians and each supplements the other. The advantage of records written by Indians for Indian readers is somewhat offset by the fact that many of the older documents exist only in the form of Eighteenth and early Nineteenth Centuries copies. The Seville texts, on the other hand, are originals, which gives them more authority as linguistic documents. These rank with the Xiu papers as a source for the history of the Maya language during the last four centuries.

SECTION OF THE HISTORY OF SCIENCE AND ALLIED INVESTIGATIONS

HISTORY OF SCIENCE—DR. GEORGE SARTON¹

Generalities—Dr. Sarton sailed from Southampton on September 21, 1934, reaching Lisbon on the 24th, in order to represent the United States Government and the Carnegie Institution at the Third International Congress of the History of Science. In the absence of the president, Dr. Karl Sudhoff of Leipzig, Dr. Sarton was acting president of that congress and delivered the inaugural speech in Porto, on October 1. The main work of the congress was done at Coimbra and it was concluded at Lisbon on October 6. Dr. Sarton sailed from Lisbon on October 7th and reached Cambridge, Massachusetts, on the 22d. A brief report of the congress has already been published in *Isis* (vol. 22, 440-55), but it is worthwhile to emphasize once more the great importance of those meetings for the organization of our studies all over the world.

As scientific genius knows no frontiers, and is largely independent of nationality, race, or creed, the history of science is essentially an international subject. However, there are linguistic and other technical difficulties which can be overcome only with the cooperation of foreign scholars. It is clear for example that it is easier for Scandinavians than for others to study the origins and development of science and learning in Scandinavia. Hence an international organization of our studies is not only important but in many cases indispensable. That organization is realized partly by an International Academy, of which the main offices are in Paris,² and partly by the International Congresses, which are triennial meetings of the Academy, open to all scholars interested in our studies.

¹ Seventeenth annual report for the period extending from July 1, 1934 to June 30, 1935 (Previous reports appeared in Year Books of the Carnegie Institution, Nos. 18 to 33, 1919 to 1935; the 12th and following also appeared in *Isis*, the latest in vol. 22, 435-439, 1935).

² The founder and permanent secretary is Aldo Mieli. The Academy was founded in 1928. The offices are established at 12 rue Colbert, Paris II (close to the Bibliothèque Nationale). The new president is Dr. Quido Vetter, and the next congress, the fourth, will take place in Prague 1937, and the fifth probably in Lausanne 1940.

The success of the Portuguese congress was due to the efforts of the Permanent Secretary and his staff, but even more so to the cooperation of our Portuguese colleagues whose hospitality was as generous and friendly as their country is beautiful—and this is saying a great deal.

Introduction to the History of Science—The work on this project, the major project of the section, continued steadily. Dr. M. C. Welborn prepared many notes and bibliographies concerning Fourteenth Century scientists of the Latin West. Dr. Sarton devoted most of his time to the Jewish scientists of the same period. The third volume of the "Introduction" will be devoted exclusively to the Fourteenth Century.

*Maya Astronomy*¹—A survey of the contributions to the study of Maya chronology—by Förstemann, Goodman, Thomas, Bowditch, Morley, Meinshausen, Spinden, Willson, Guthe, Teeple, Thompson, Martínez Hernández, Ludendorff, Palacios, Roys and Beyer—revealed the possibility of a new approach to the problem of correlating Maya and Christian dates.

In 1913, Meinshausen recognized that the pages 51 to 58 of the Dresden Codex contain a table of eclipse syzygies. Willson's attempt to derive a day-by-day correlation based on this table was unsuccessful; the posthumous publication, in 1924, of Willson's unfinished investigation conveyed, unfortunately, the impression that his negative results were final. Two erroneous assumptions underlying Willson's unfinished investigation ought to be mentioned here: first, that partial eclipses of the sun may be disregarded; and, second, that lunar eclipses do not have to be considered; moreover, he overlooked the existence of the tenth "picture," at the bottom of page 58 of the Dresden Codex. An example of a partial solar eclipse visible in the Maya territory is quoted in the bibliography accompanying this report; examples of lunar eclipses at Dresden "picture" intervals will be found in the table below.

In 1925, Teeple published his paper on the glyphs C, D and E of the Supplementary Series of the inscriptions—a short and brilliant paper equaling in importance that of Meinshausen. Teeple's subsequent investigations of the lunar calendar of the Maya led him to consider the Dresden table of eclipse syzygies, but he did not attempt to exhaust the correlation possibilities it offers; incidentally, he disregarded or overlooked, like Willson, the existence of the tenth "picture."

A study of the periodicity of groups of eclipses had to be made, in order to bring out the correlation possibilities offered by the pages 51 to 58 of the Dresden Codex, on the one hand, and by the Supplementary Series, especially by glyph C, of the inscriptions, on the other. Cylindrical diagrams based on the Mec (Maya eclipse cycle of 11960 days = 405 lunations = 69 eclipse semesters = 23 double tzolkins) were constructed; they permit us to trace the development of the ideas which led to the introduction of Supplementary Series and to the compilation of tables of eclipse syzygies. The following table may be used as an example of the periodicity of groups of lunar eclipses which were visible in the Maya territory and occurred at Dresden "picture" intervals.

¹ This report was prepared by Dr. A. Pogo who is now devoting most of his time to this project.

The total solar eclipse of -43 October 11.9, preceding the first group of lunar eclipses of the table, was visible in the Maya territory, at sunset; the close conjunction with α Libræ offered an opportunity of counting lunar cycles from a definite point in space as well as in time.

Lunar saros series	Group at "picture" intervals	First exeligmos return	Second exeligmos return	"Picture" numbers	Intervals in days
L 76	-43 Oct 27 4	11 Nov 20 5	65 Dec 31 5	X	
L 93	-41 Mar 13 0	13 Apr 14 5	67 May 17 5	I	502
L152	-37 Dec 19 2	18 Jan 20 3	72 Feb 22 4	II	1742
L187	-34 Oct 18 3	20 Nov 19 3	74 Dec 22 3	III	1034
L 5	-30 Feb 10 2	24 Mar 14 2	78 Apr 16 0	IV	1211
L 64	-26 Nov 18 4	28 Dec 20 5	83 Jan 22 6	V	1742
L 99	-23 Sep 16 1	31 Oct 19 1	85 Nov 20 2	VI	1033
L140	-19 Jan 9 2	35 Feb 11 2	89 Mar 15 2	VII	1211
L193	-15 Apr 23 5	39 May 26 4	93 Jun 27 4	VIII	1505
L 11	-12 Aug 16 1	42 Sep 18 1	96 Oct 20 2	IX	1211
L 35	-10 Jul 26 3	44 Aug 27 2	98 Sep 29 2	X	709
					11960

A preliminary survey of the correlations derived from groups of eclipses separated by Dresden "picture" intervals shows that a considerable amount of work will be needed in order to eliminate the spurious solutions; the final day-by-day correlation based on the Dresden table of eclipse syzygies and on the lunar cycles recorded in the Supplementary Series of the inscriptions must be compatible with a simple interpretation of the Venus table of the Dresden Codex and of the Venus dates of the inscriptions.

Other Investigations—Dr. Welborn collected materials for an article on the Italian physician Christophorus de Honestic (d. 1392) and for another on medical deontology in the Fourteenth Century.

Dr. Sarton continued the Arabic studies which are fundamental for all investigations concerning mediæval science, and he investigated the genesis of our ideas on cathodic rays.

Editing of Isis—Isis is a complementary publication to the Introduction. The latter is a systematic survey of our knowledge of the science and learning of definite periods (thus far, from Homer to the end of the Thirteenth Century); the former, a collection of materials concerning that history in all times and places as it was developed by men of all nations, races and creeds, and it is also a repository for all corrections and additions relative to the published parts of the "Introduction." Thus if it should ever be necessary to prepare a new edition of the "Introduction," many of the necessary data would be immediately available in their proper sequence.

During the year 1934-35, five numbers of Isis were published (61 to 65), forming the whole of volume XXII and parts of volumes XXI and XXIII, a total of 1323 pages, 27 plates, 35 figures, 72 facsimiles. These five numbers contain 31 memoirs, 38 shorter items, 80 reviews and 1919 bibliographic notes.

The first volume of Osiris is being prepared to appear in January 1936. Osiris will be a collection of longer memoirs, or of series of memoirs devoted

to single topics. It will be supplementary to *Isis* and to the "Introduction" (see *Isis*, 22, 437). Thanks to *Osiris*, it will be possible to print in *Isis* a larger number of shorter papers, and the variety and interest of *Isis* will thus be considerably increased. However, these beneficial effects will not be felt at once, but only after the lapse of another year or two.

Center of Research in the History of Science and Learning—The offices of this Section, kindly lent to Dr. Sarton by Harvard University, have gradually become, thanks to the *Introduction* and to *Isis*, an international center of information for everything that concerns our studies. The collections of pamphlets, reprints, etc., kept in these offices are probably the most complete of their kind available anywhere, and they increase very fast. The new reprints grow to a two-foot pile in six weeks and are then distributed according to subjects in pamphlet boxes (more than four hundred double sized boxes). Our collection of books is not as large, but we have immediate access to the more than three million books of the Harvard University Library.

This increase of our apparatus is very satisfactory, for it implies a gradual improvement in our work, but it is also somewhat disquieting, for it raises many difficulties. Problems of classification, registration, shelving, etc., which were hardly noticeable when the collections were small are becoming more and more obtrusive. Moreover the time is approaching when further increase will no longer be possible in the present rooms.

Inquiries which can be answered without too much research are generally handled within a few days. If more time and labor are involved than can be spared, the inquiry is courteously acknowledged without answer. The number of interruptions in the form of visits, interviews, correspondence is constantly growing, and thus the time left for real work is constantly reduced.

Dr. Pogo is doing his work in the Library of Congress, study 33, Washington, D. C.; all others in the Harvard Library, Study 185-9, in Cambridge, Massachusetts.

HISTORY OF GREEK THOUGHT, BY W. A. HEIDEL

Dr. Heidel has continued the researches described in former reports. *Hecataeus and the Egyptian Priests in Herodotus, Book II*, is in press and is shortly to be issued as a *Memoir* of The American Academy of Arts and Sciences. *The Frame of the Ancient Greek Maps* is ready for the printer and may be expected to be published soon.

Concurrently with the detailed study of the extant documents of early Greek science and philosophy, Dr. Heidel has devoted the year to recent and current literature dealing with these subjects and especially to the background and possible antecedents and sources of Greek adventures in science. One need not have reached a dogmatic conclusion respecting the rival theories of the free transmission of ideas from one people to another or of the spontaneous and independent development of similar notions and procedures in different centers; but the historian, though open-minded and of necessity in some measure resorting to speculation, is bound to weigh the probabilities in every individual case. He will recognize a greater probability in favor of an actual relation between Greek and Oriental views in the sphere of religion, since Greek religion in many respects has its roots in the distant past among

peoples certainly or presumably connected with Asia. In like manner he will concede a probability that contact with Phœnicians may have mediated an acquaintance with the rudiments of mathematics developed in the Orient. But he will require firmer grounds for the assumption of the transmission of more highly developed speculations and of ideas which may possibly have been suggested by general human experience or by phenomena and observations open to the Greeks and in keeping with the stage of their development. One who is acquainted with the literature of the subject will be aware that these considerations are often too little regarded. Sober judgment is required and something more than an eclectic digest based on a bibliographic survey.

RESEARCH IN PALAEOGRAPHY—E. A. LOWE¹

After field work in Paris during July and August 1934, Dr. Lowe, accompanied by Dr. Bischoff, returned to England in order to put into final shape the material comprising the second volume of *Codices Latini Antiquiores*. Important manuscripts in London, Cambridge, Durham, Lichfield and Oxford were reexamined and, by the end of November, 100 items of C.L.A. II (the whole volume contains 160) were sent to press.

In order to ascertain whether the Insular manuscripts on the Continent possessed features which distinguished them from Insular manuscripts in England and Ireland, advantage was taken of the six weeks' Christmas holiday to study the Insular manuscripts in Turin, in the Ambrosiana of Milan, in the monastery of St. Gall, in the University Library at Bâle, and in the Bibliothèque Nationale, Paris. While in Paris it was possible to resume the summary inspection in the stacks of the first 8000 manuscripts of the *Fond Latin*, which are inadequately catalogued. This search for new C.L.A. items, begun by the late and much regretted Mgr. Lacombe, is being continued with the assistance of M. Lauer, the Keeper of Manuscripts of the Bibliothèque Nationale, whom it is a pleasure here to thank publicly.

The second half of the past year was spent in preparing the remaining 60 items for press. The whole material, apart from the Preface, is now in the printer's hands, including the negatives for making the 160 colotype facsimiles. The volume is expected to appear in the month of December.

Warm thanks are due to the authorities at Bodley's and the British Museum for innumerable courtesies, also to the librarians of Corpus Christi, Gonville and Caius, Magdalene, and Trinity Colleges of Cambridge, as well as to the authorities of the Cathedral Libraries of Durham, Lichfield, Hereford and Salisbury, to the heads of the University Libraries of Turin and Bâle, and especially to Dr. Galbiati of the Ambrosiana who generously gave permission to use the Library when it was closed. Dr. Gruppy, of the John Rylands Library, and Mr. Roberts of St. John's College, Oxford, have put Dr. Lowe under great obligation by their liberality in allowing the use of four interesting papyri before their official publication. Finally, special thanks are due to M. Van Moë of the Bibliothèque Nationale through whose generous assistance it has been possible to obtain the large mass of photographs needed for the Paris volume.

¹ For previous reports see Year Books Nos. 9-33.

DEPARTMENT OF MERIDIAN ASTROMETRY ¹

BENJAMIN DOSS, DIRECTOR

The report of the Department for the year 1933-34 stated that it was anticipated that the work on the general Catalogue would be completed by the end of the calendar year 1935. This prediction will be very nearly fulfilled. In addition the manuscript of the first volume, which will include the stars of right ascensions 0 to 6 hours, has been made out through the first four and a half hours and will be completed before the end of the calendar year. Work on the trigonometric computations to give the positions and motions of the southern circumpolar stars will carry over into next year. It is anticipated, however, that these computations will keep pace with the preparation of the manuscript of the catalogue, which in itself forms a large undertaking. It involves the copying of over five-million characters, which must be doubly checked, typewritten and checked again before being printed.

In answer to a general request from astronomers that spectral types be included in the catalogue for the purpose of assisting statistical investigations based upon proper motion and spectral type, the director approached Dr. Harlow Shapley, Director of the Harvard College Observatory, with the request that he furnish the types of as many as possible of those stars in the catalogue for which no types have previously been determined. Dr. Shapley has most generously undertaken this work, and the results for the first three hours of right ascension have been incorporated in the manuscript. However, the task is time consuming, it is undertaken in addition to regular programs, and progress may not keep step with the preparation of the manuscript of the General Catalogue. In this case we will be faced by the alternative of postponing for a short time the submission of the manuscript for publication or proceeding with publication without the inclusion of the types which the Harvard Observatory is preparing to furnish.

DETAILED REPORT ON PROGRESS

The report of progress in the formation of the General Catalogue is a continuation of the reports offered in previous years. As will be seen below, those items listed in the report of last year have been practically completed, and the final steps are well along. With the exception of some work on the trigonometric computations for the circumpolar stars and the preparation of the introduction and appendices, our task for next year will consist mainly in preparing the manuscript, checking it and proof-reading the typewritten copy.

4. The remainder of the solutions of the normal equations giving the motions and final positions at epoch have been completed and checked.

5. The extension of the ephemerides to give the final positions for 1950 of the last 4500 of the southern miscellaneous stars was completed and checked.

6. The operation requiring the most time outlay during the past year was the computation of precessions and secular variations for the last 14,500 of the southern stars. These have been completed in duplicate and checked.

7. Third terms in the precessions were computed for the same stars, completing this operation.

¹ Address: Dudley Observatory, Albany, N. Y.

8. The centennial variations in the proper motions of the last 7500 southern stars were computed and checked.

9. The entry of the data from the solutions on the catalogue cards has been completed and checked for all the northern stars except the circumpolars. A large part of the data for the southern stars has been entered to 16 hours of right ascension and checked to 12 hours.

10. The search for unusual and gross errors has been completed.

11. A check comparison between the preliminary and final secular variations has been completed.

12. The computations of the probable errors for 1950 were completed for the northern stars and to 11 hours in the case of the southern.

13. A comparison of the Struve and Newcomb proper motions, to detect errors, is complete to 11 hours.

14. Data on double stars, taken from the double star catalogues of Aitken and Innes and to appear in the remarks column of the General Catalogue, have been entered to 9 hours.

15. Data on variable stars, taken from Prager's 1935 catalogue, have been entered for the first six hours.

16. The trigonometric computations for the circumpolar stars, those within 10° of either pole, are well advanced, but considerable work will be required to bring them to completion. For the northern stars the reductions are complete, the cards and ephemerides are drawn off to 18 hours of right ascension and are checked to 12 hours. For the southern circumpolars the computations are complete and checked to 12 hours for stars south of -85° and the cards and ephemerides are drawn off. For stars between declinations 80° and 85° the computations are complete and checked, and the cards and ephemerides drawn off to 8 hours of right ascension.

STAFF

The only change in the staff during the year resulted from the illness of Miss Grace Buffum, computer, who is temporarily employed on part time. Miss Isabel Little has been employed on part time to fill the gap. Dr. Sebastian Albrecht, research associate, has continued to assist with computations on the General Catalogue.

MOUNT WILSON OBSERVATORY ¹

GEORGE E. HALE, HONORARY DIRECTOR
WALTER S. ADAMS, DIRECTOR
FREDERICK H. SEARS, ASSISTANT DIRECTOR

SURVEY OF THE YEAR'S WORK

The outstanding astronomical phenomenon of the year has been the outburst of Nova Herculis. As to what happens when a nova suddenly appears we have little certain knowledge. The catastrophic nature of the occurrence is evident, and the course of some of the physical changes undergone by the star is gradually becoming clear; but the essential conditions preceding the outburst and the circumstance that sets it under way are still largely matters of speculation.

There is, however, perhaps more than a hint—although only one of several possibilities—in Milne's recent studies of stellar constitution. These studies involve mathematical discussions of hypothetical models of stars consisting of spheres of gas. Definite distributions of pressure, density and temperature within the sphere follow from the assumed physical properties of the gas and the conditions affecting its radiation. Under certain circumstances a critical state occurs such that the gas sphere is no longer able to maintain its structure. The sphere collapses into one of higher density and much smaller volume with an explosive development of radiation. Temperature and luminosity are enormously increased, and part of the gaseous material may be driven away into space as a nebulous shell. This theoretical approach to the problem is suggestive, but hardly convincing because it is by no means certain that the gas-sphere models really correspond to stars. Moreover, it does not seem to provide for the observational fact that novæ usually occur close to the galactic plane.

Observationally, what happens, and at this stage it is the observational data that require emphasis, is that an inconspicuous telescopic star, within a few hours or a few days at most, rises to a maximum of luminosity perhaps ten or twenty thousand times greater than that before the outburst, then, with many fluctuations in brightness, slowly declines until after weeks or months it is again inconspicuous and easily lost among other faint stars. Some months after the outburst, powerful telescopes may show the development of a disk or ring of nebulosity surrounding the star, which expands, apparently at a uniform rate.

The real complexity of the phenomenon, however, is revealed by the star's spectrum. Continuous during increasing brightness except for faint absorption lines, the spectrum suddenly alters near the time of maximum light; very broad emission bands then appear, especially of hydrogen, bordered on their violet edges by corresponding absorption lines. The wide emission bands indicate the presence of an expanding gaseous envelope. The portion of the envelope in front of the star absorbs radiation coming from the star itself and produces the adjacent absorption lines. The large displacement of the absorption lines from their normal position, as well as the great width of the emission bands, indicates uprushing velocities of hundreds of kilometers per

¹ Address: Mount Wilson Observatory Office, Pasadena, California.

second. Structural details appear within the bands, and the corresponding absorption lines may be double or even more complex, thus suggesting the presence of two or more shells, expanding at different rates, and of other features not yet understood. Later, as the light declines, the spectrum gradually alters. The characteristic lines of a diffuse nebula appear, widened into bands, and in turn slowly fade away, while the spectrum of the central nucleus finally changes into that of an O-type star.

The extraordinary transformations and the scale on which they occur render the phenomena of novæ among the most impressive known to the observer, and probably also among the most fruitful for the study of stellar constitution. For Nova Herculis, however, it is still too soon even to summarize the observational results. Several features undoubtedly will make its appearance noteworthy: first, the relatively slow approach to maximum, at least to the first maximum observed, thus permitting detailed study of early stages of its spectral development; second, the star's unusual brightness and slow decline from maximum, giving special opportunity for favorable observation; and, finally, its observation with the high dispersion of the coude spectrograph under conditions not hitherto available. The optical power of this instrument, together with the great number and the sharpness of the widely displaced absorption lines, will certainly yield a rich fund of information when the observations are discussed.

Another occurrence of noteworthy interest has been the extensive observation of the eclipsing variable star ζ Aurigæ. Once every thousand days (973 to be exact) a relatively small, hot, B-type star, revolving about a much larger and more massive K-type giant, passes behind the giant star and remains totally eclipsed for about 37 days. The dimensions and the physical characteristics of the stars and their relative orbit are of interest, but, except in the length of the period, present nothing unusual. Immediately preceding and following the interval of total eclipse, however, are two stages of partial eclipse, each lasting 1.7 days, during which light from the small B star shines through the extensive and tenuous atmosphere of the K-type giant and reaches the observer after having suffered absorption by the gases in this atmosphere. As the partial eclipse progresses, the spectral pattern alters. Lines change in intensity and appear or disappear in a manner determined by the rate of motion and the abundance and the distribution of the elements in the atmosphere of the K-type giant. It is possible to eliminate the influence of the light of the K star and thus isolate completely the effect produced by the atmosphere of this star on the radiation that it transmits from the small B-type companion. This effect is a record of the constitution of the atmosphere itself, which can thus be studied under conditions that are unique. The results obtained indicate serious defects in all the present hypotheses concerning the constitution of stellar atmospheres.

The long-period variable R Aquarii, surrounded by faint diffuse nebulosity, presents a complicated sequence of phenomena which may include features of general astrophysical interest. Its complex spectrum includes that of a typical long-period variable; the spectrum of a gaseous nebula, which changes in intensity and shows remarkable irregularities in the displacements of its lines; and, finally, that of an early-type "companion," first seen in

1922, which also varies in a puzzling manner. The spectroscopic observations show that both the M-type star and the companion contribute to the observed variation in light, and with their aid the light-curve may be analyzed into its component parts. Objects of this kind, like novæ, give valuable information on stellar constitution, although the application of what is learned is not always immediately evident. The fact that they change and that transitions are observable oftentimes suggests a connecting link between isolated physical states in different stars.

The fundamental part played by the distances of the stars in any study of the structure of our stellar system is obvious. The difficulties incident upon the accumulation of information on stellar distance are well known. The straight-forward trigonometric method, which utilizes the shift in the position of the earth from one side of its orbit to the other, on the opposite side of the sun, can be applied only to the nearest stars. The introduction twenty years ago of the spectroscopic method, which relieves to a large extent the restriction in distance, therefore afforded the means of an important advance. The first large accumulation of results, including 1646 stars, was published in 1920. Since then the method has been refined, the early results have been revised, and much additional material has been collected. The appearance of a second list comprising the spectroscopic parallaxes of 4179 stars, which has recently come from the press, marks the completion of another stage in an investigation which underlies or in some way bears upon every phase of the Observatory's work.

Even the spectroscopic method of determining stellar distance has, however, its limit of applicability. Very distant objects are, in general, so faint that their light is insufficient for spectroscopic analysis. In certain cases the observer may then have recourse to the remarkable relation between the cycle of light changes in a Cepheid variable and the intrinsic brightness of the star. The longer the period of light variation, the more luminous the star. By determining the period, the intrinsic brightness can be found; and then, just as in the spectroscopic method, comparison with the star's apparent brightness gives its distance. The use of Cepheid variables in determining the distances of globular clusters and extra-galactic nebulae has done much to center interest upon this important class of stars. In addition, they have an interest of their own, for their changes in brightness, caused apparently by pulsations of the gaseous mass of the star, set them in a position of importance in any study of the internal constitution of stars. Finally, not only can their distances be determined with accuracy; they are themselves objects situated at very great distances, and hence in a key position for a study of such questions as the absorption of light in space and the rotation of the galaxy. A program of spectroscopic observation of Cepheids pursued for many years has been practically finished, and some of these questions are now under discussion.

Occasional sun-spots belonging to the old cycle were still to be seen in low latitudes during the year 1934. The sharp increase in the numbers appearing in high latitudes from 2 in 1933 to 52 in 1934 indicated, however, that the new cycle was well under way; and it now seems clear that the intensity of the sun's ultra-violet radiation has also passed a minimum. The magnetic

polarities of spots maintain their customary regularity in the distribution of the algebraic sign of the field and firmly establish the complete reversal of signs in the new cycle relative to the old announced a year ago. Study of the frequencies of dark hydrogen flocculi suggests that they follow the main fluctuations in the earth's magnetic field more closely than they do those of the sun-spot curve. The intensities of the bright hydrogen associated with spot groups show no correlation with the sun-spot cycle. Continued investigation of the sun's rotation, with special attention to systematic errors produced by scattered light, increases the rotational values obtained since 1914 by about 4 per cent and makes the Mount Wilson measures as a whole much more consistent. Further improvements in sensitizers for photographic plates have made it possible to push the limit of spectroscopic observation on the sun another thousand angstrom units into the infra-red. Investigations in the infra-red region are still largely of such fundamental matters as the scale of wave-lengths and the intensities of lines. As a rich source of astrophysical information, the field is still almost untouched.

Although the constitution of the moon can not be studied with the spectroscope as that of the sun or a star is studied, special methods which partially overcome this disadvantage are being used successfully to determine some of the physical properties of the moon's surface rocks. The investigation is only one phase of the work of the Moon Committee, composed of specialists from different fields of science. Measurements of radiation from the planet Mercury show that the relations between phase angle and both planetary heat and reflected sunlight are similar to those for the moon. The temperature at the point directly beneath the sun varies 130° C. with the position of the planet in its orbit (282° C. to 412° C.) but is always far above that of boiling water.

Equally important with distances as fundamental data are the apparent magnitudes of the stars. In fact, the magnitude of a star must be known before spectroscopic criteria or Cepheid variability can be used to find its distance. The determination of suitable standards of brightness, well distributed in the sky, is one of the essential steps in supplying the photometric data needed to obtain the distances not only of stars but also of globular clusters and extra-galactic nebulae. Much progress in standardization is now being made, partly of the faintest stars observable with the 100-inch telescope and partly of stars brighter than the twelfth magnitude, whose brightness is still imperfectly known in spite of the fact that they are within easy reach of small telescopes.

Directly associated with measurements of brightness are measurements of color, which have a significant bearing on the absorption of light by interstellar clouds of dust and gas. Measurements of this kind made with the photoelectric cell are proving of exceptional value. Observed in this manner, B-type stars, globular clusters and extra-galactic nebulae all reveal the stratum of absorbing material close to the galactic plane and a dependence of color on position which denotes increasing absorption as the direction of the center of the stellar system is approached.

The studies of extra-galactic nebulae continue to bring forth results of outstanding interest. Red-shifts of spectral lines corresponding to recessional

velocities of 24,000 and 39,000 km. per second have been confirmed, and for an object in a faint cluster of nebulae in Ursa Major a value of 42,000 km. per second, from a single spectrogram, however, is now available. The evaluation of the influence of the red-shift on the apparent magnitudes of these remote objects has already become a pressing matter, because any calculation of the distribution of nebulae in space depends on the values of the magnitudes freed from this disturbance. The amount of the correction, however, will be determined by the physical interpretation of the red-shift itself; and although we know only motion in the line of sight as a competent explanation, it would be incautious on present evidence to assert that motion is certainly the correct interpretation.

An intensive study of red-shifts, regarded as the consequence of motion, for 30 nebulae in the Virgo Cluster has led to a number of striking conclusions, among them a value for the average mass of the individual nebulae which is a hundred times that derived from isolated non-cluster nebulae. These results are not necessarily inconsistent; but if the high value for the cluster nebulae is of the right order, it probably indicates the existence of a great amount of inter-nebular material within the cluster. The question is of great importance for cosmological investigations.

In the past the physical characteristics of nebulae have been somewhat neglected because interest then centered on their distribution and motions. A beginning has now been made, however, with some of the elliptical nebulae. One of these objects, M 22, shows no appreciable polarization of its light; its nucleus apparently may be regarded as a separate entity having an angular diameter of the order of 1"; its spectrum along the major axis is constant, the type being dG3, a little later than that of the spirals. Regarded as a gigantic star cluster, its stellar content would seem to be only a thousandth part that of our stellar system, whereas the space density of stars at its center would be of the order of ten million times that near the sun.

The extraordinary advance made in theoretical spectroscopy in recent years has put heavy demands on the physical laboratory. To utilize the full advantage of these gains on the theoretical side, they must be made applicable to definite astrophysical problems. For this purpose term analyses of the spectra of the different elements must be available. At this point laboratory data on the positions, intensities and temperature characteristics of spectral lines become an essential. For some years the complicated spectra of the rare earths have been under observation in the Laboratory of the Observatory. The magnitude of the task is suggested by the numbers of the lines studied and classified—for example, 1200 for europium, 3000 for gadolinium, and nearly 4500 for samarium. The stronger lines of the ionized spectra of all three elements appear in the sun, but not the neutral lines, in accordance with the usual behavior of the rare earths. The experimental work indicates that the phenomenon is one of abundance. Low vapor density affords so few opportunities for recombination of electrons with ionized atoms that neutral lines do not appear. The inference is, therefore, that these elements are scarce in the sun, as on the earth.

The publication of the final results of the measurement of the velocity of light closes an investigation started ten years ago by the late Albert A.

Michelson of the University of Chicago. Four series of measures, each including several hundred observations made with a mile-long vacuum pipe line during intervals of 2 to 5 months, give mean values which show an average deviation of 3.5 km. per second and a final mean of 299,774 km. per second. The internal agreement points toward an uncertainty of 1 or 2 km. per second in the final result. The value found from the measures made in 1926 (a few of low weight in 1925) over the open-air path of 22 miles between Mount Wilson and Mount San Antonio was 22 km. per second higher. The cause of this disagreement is not known. The observing conditions in the two cases were, however, entirely different: in one, a relatively short path of 8 or 10 miles, obtained by multiple reflections within the pipe line under a pressure of only a few millimeters of mercury; in the other, an air path of 45 miles that twice traversed a wide deep canyon. However we rate the influence of this difference in conditions, a striking feature of the recent measures should be noted. Even with all possible care in the manipulation of the apparatus, abnormal values of the observed velocity, sometimes high and sometimes low, persisted at times during days or even weeks, thus indicating the existence of disturbing influences of unknown origin. It is possible that the value of the velocity from the 1926 measures is systematically affected by error of this kind. The two-year interval covered by the four recent series and the general accordance of their respective results suggest, on the other hand, that the influence of any such error on the adopted mean velocity must be relatively small.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his investigations of the general magnetic field of the sun, giving special attention to improvements in the method of measurement. He has also continued his supervision of the plans for the 200-inch telescope. Dr. Walter S. Adams, Director, carried on investigations in stellar spectroscopy and conducted the administrative work of the Observatory until May 18, when he left for Paris to attend the meeting of the International Astronomical Union. Dr. Frederick H. Seares, Assistant Director, served as Acting Director after May 18. He has continued his work on the standardization of stellar magnitudes and given much time to editorial supervision of the Observatory publications.

Dr. Arthur S. King, Superintendent of the Physical Laboratory, has been occupied chiefly with temperature classifications of lines in rare-earth spectra and the segregation of the lines important as a basis for term analysis of the various spectra. Dr. John A. Anderson has been concerned with the completion and perfection of the vacuum spectrograph and with administrative duties connected with the 200-inch telescope. Dr. Edwin Hubble has reviewed the numerical data resulting from his extended surveys of extragalactic nebulae and the results now available on the distances and velocities of nebulae. Jointly with Professor Richard C. Tolman of the California Institute, he has studied the bearing of the observational results on theoretical explanations of the red-shift. Mr. Harold D. Babcock has continued his study of the infra-red solar spectrum with special attention to the scale

of wave-lengths. He has also devoted much time to the perfection of the new ruling machine. Dr. Paul W. Merrill has extended his spectroscopic observations of various classes of stars, among them the long-period variables, of which R Aquarii was studied in detail. Professor Alired H. Joy, Secretary of the Observatory, has practically concluded his comprehensive spectroscopic study of Cepheid variable stars. Dr. Seth B. Nicholson has supervised the regular observations of solar and sun-spot activity, solar rotation and the polarities of spots, and has assisted in the study of methods of measuring spectrograms taken for the determination of the sun's general magnetic field. Dr. Francis G. Pease has finished the discussion of the measurement of the velocity of light and continued his work connected with the design of the 200-inch telescope. In December he was present at the successful pouring of the 200-inch disk of pyrex glass to be used for the mirror of this instrument. Dr. Adriaan van Maanen has carried on his measurements of trigonometric parallaxes and proper motions. In May he left Pasadena for attendance at the meeting of the International Astronomical Union in Paris. Dr. Roscoe F. Sanford has completed his investigations of N- and R-type stars and of three Cepheid variables and has observed numerous spectroscopic binaries and other stars of variable radial velocity. Dr. Edison Pettit has made observations of ultra-violet solar radiation and the forms of prominences, and, jointly with Dr. Nicholson, has discussed the measurements of radiation from Mercury. During July and August Dr. Pettit visited the Yerkes Observatory to carry on observational work on prominences. Dr. Walter Baade has been occupied chiefly with the magnitudes of faint stars in several Selected Areas and integrated magnitudes of nebulae and with variable stars in a globular cluster. Dr. Gustaf Strömberg has taken part in observations of stellar spectra and continued his cosmological studies and other theoretical investigations. Dr. Theodore Dunham jr. has devoted much time to the design and experimental tests of the new coude spectrograph and has undertaken a systematic study of the intensities and contours of spectrum lines. Mr. Milton Humason has made numerous spectroscopic observations of faint dwarf stars, novae, globular clusters and extra-galactic nebulae. Dr. Sinclair Smith has accumulated spectroscopic data on extra-galactic nebulae with special reference to their bearing on various physical characteristics of the nebulae. Mr. Ferdinand Ellerman has shared in the solar observations and continued in charge of most of the general photographic work. Dr. Robert S. Richardson has given attention to the relation of solar activity to terrestrial magnetic disturbances and devoted much time to a study of the observations of solar rotation. Dr. Robert B. King has made laboratory observations of multiplet intensities and Zeeman patterns. Mr. Joseph Hickox has made regular solar observations on Mount Wilson and continued to test photographic emulsions.

In the Computing Division Miss Louise Ware has been engaged with measurements of the intensities of solar lines, both center and limb, in the region $\lambda 5400$ - $\lambda 6000$. Miss Elizabeth E. Sternberg has continued her work relating to solar activity and sun-spot phenomena, preparing character figures and much of the solar material supplied to other observatories. Mr. Edward F. Adams has measured spectrograms relating to solar rotation and the sun's

general magnetic field. Miss Myrtle L. Richmond has continued to measure and reduce the curves recording ultra-violet solar radiation and has assisted in the radiation measurements of Mercury and with miscellaneous computations. Until his resignation on September 15, Mr. Howard C. Willis measured stellar parallaxes and proper motions. Since November 1, Dr. P. Th. Oosterhoff has continued this work and, in addition, undertaken researches in photometry. Miss Mary C. Joyner, as in former years, has assisted Dr. Seares and has collaborated with him in the derivation of standard magnitudes. Miss Cora G. Burwell has continued to aid Dr. Merrill in his spectroscopic work. Miss Elizabeth MacCormack has devoted much of her time to the measurements of spectrograms and to special computations, and has collaborated with the Director in a study of abnormal displacements of stellar lines. Dr. Olin C. Wilson and Mr. William H. Christie have continued the regular observation and reduction of radial velocities and have jointly studied the important data associated with the eclipse of ζ Aurigæ. Dr. Wilson has also given much attention to the interpretation of the spectra of novæ. Miss Ada M. Brayton has been engaged with miscellaneous calculations and the final details of the manuscript and proofs of the Catalogue of Spectroscopic Parallaxes. Mr. Wendell P. Hoge has continued to assist Mr. Babcock in investigations of the infra-red solar spectrum. Miss Dorothy J. Carlson, special part-time computer, has assisted Dr. Dunham in the study of line intensities and contours. Dr. R. M. Langer, also special part-time computer, has made measures of the sun's general magnetic field. Miss Elizabeth Connor, Librarian, has continued to aid in the editorial work of the Observatory.

Dr. Henry Norris Russell, Research Associate and Director of the University Observatory, Princeton, spent two of the autumn months in Pasadena, engaged in theoretical investigations in spectroscopy. Dr. Joel Stebbins, Research Associate and Director of the Washburn Observatory of the University of Wisconsin, was in residence at Pasadena from January until April and, in collaboration with Dr. Albert E. Whitford, National Research Fellow, continued his studies of stars and nebulae with the aid of the photoelectric photometer.

Among visiting astronomers who carried on researches at the Observatory at various times during the year were Dr. Frank E. Ross of the Yerkes Observatory of the University of Chicago, who made photometric observations and extended his photographic map of the Milky Way; Dr. S. A. Mitchell, Director of the McCormick Observatory of the University of Virginia; Dr. John C. Duncan, Director of the Whittin Observatory of Wellesley College; Dr. Caroline E. Furness, Director of the Observatory of Vassar College; Dr. O. L. Dustheimer, Professor of Mathematics and Astronomy at Baldwin-Wallace College; and Dr. Charlotte E. Moore, University Observatory, Princeton. Dr. Fred. E. Wright of the Geophysical Laboratory of the Carnegie Institution spent the summer months of 1934 on Mount Wilson engaged in researches on the moon. Since his arrival on September 22, Mr. A. D. Thackeray, Fellow on the Commonwealth Fund, has carried on solar investigations. Dr. Rupert Wildt, Fellow of the Rockefeller Foundation, in residence since February 11, has been occupied with spectroscopic investiga-

tions. Dr. Rudolf Minkowski arrived in Pasadena on June 1 for a year's residence as a visiting investigator. During the summer months Mr. Horace Babcock and Mr. William Humason served as temporary observers.

With deep regret the Observatory records the death on April 26, 1935, of Dr. Charles Edward St. John, a distinguished member of its staff from 1908 until 1930 and Research Associate during the years 1930 to 1935. St. John made many notable contributions in the field of solar physics and his personality and enthusiasm were a constant source of inspiration to the members of the staff, especially throughout the formative years of the Observatory.

OBSERVING CONDITIONS

Observations were made during the whole or part of 287 nights, a number close to the average of 289. Solar observations were obtained on 268 days, about 40 less than the average, owing to exceptional cloudiness during daylight hours. The extreme temperatures were 99° F. on July 27, 1934, and 17° F. on March 9, 1935. The snowfall was moderate, only 34 inches; but the total precipitation, 46.24 inches, was 50 per cent above normal and the third highest in 31 years. The accompanying table shows the distribution of observing time according to the record for the 60-inch telescope.

Month	Observations			Month	Observations		
	All night	Part of night	None		All night	Part of night	None
1934.				1935.			
July ...	28	1	2	January	11	11	9
August	28	3	0	February	14	6	8
September .	21	4	5	March	12	8	11
October .	21	4	6	April	15	4	11
November	13	10	7	May	21	4	6
December .	12	7	12	June	26	3	1
				Total	222	65	78
				Mean 33 years	203	86	76

SOLAR RESEARCH

The usual observations of the numbers, areas and polarities of sun-spots have been continued, and daily records have been made with the spectroheliograph. Daily measurements of ultra-violet radiation and of the horizontal intensity and direction of the earth's magnetic field have also been continued, and the magnetic character figures for each day have been supplied to the Department of Terrestrial Magnetism of the Carnegie Institution for publication in *Terrestrial Magnetism*. Special observations include spectral and photometric studies of sun-spots, spectrograms of the chromosphere in the near infra-red, studies of prominences with the spectroheliograph, and of the radiation-curve of the sun with special reference to the ultra-violet region.

Since April 1, 1935, daily observations of bright hydrogen flocculi have been made during at least one hour each afternoon. These observations

include hydrogen spectroheliograms taken at four-minute intervals, supplemented by observations with the spectrohelioscope. The results are communicated to Commission 11 of the International Astronomical Union as a contribution to the cooperative program of solar observing with the spectrohelioscope. It is planned to make the photographic record automatic and continuous, at least during the afternoon hours.

Areas and positions of sun-spots on 82 days have been supplied to the Naval Observatory for publication in the *Monthly Weather Review*, and reports of the number of sun-spots observed have been communicated daily to Science Service at Washington. Estimates of character figures of solar activity have been made by Nicholson and Miss Sternberg on 283 days in 1934 for calcium flocculi and on 285 days for hydrogen flocculi, and have been sent to Commission 10 of the International Astronomical Union for publication in its Bulletin. The measurements of ultra-violet radiation by Pettit and Miss Richmond are also published in this Bulletin.

The mirrors of both tower telescopes were coated with aluminum in November 1933. They have given excellent service and the surfaces appear still to be as bright as when first coated.

SOLAR PHOTOGRAPHY

Direct photographs of the sun were made with the 60-foot tower telescope on 268 days. The solar observers, Ellerman, Hickox, Nicholson and Richardson, also obtained plates with the 13-foot spectroheliograph as follows:

H α of the disk	274
K $_2$ of the disk	262
K of prominences	320
H α of spot groups	10

Spectroheliograms have been sent regularly to the Kodaikanal and Meudon observatories as in previous years.

SUN-SPOT ACTIVITY

During the calendar year 1934, solar observations were made at Mount Wilson on 326 days, on 140 of which no spots were visible. The monthly means of the numbers of groups observed daily during the past two and one-half years are given in the accompanying table.

Month	Daily number			Month	Daily number	
	1933	1934	1935		1933	1934
January	(1 4)	0 3	1 8	July	0 6	1 1
February	1 5	0 9	2 3	August	0 1	0 8
March	1 0	0 6	2 2	September	0 5	0 6
April	0 3	0 9	1 2	October	0 4	0 6
May	0 5	1 8	2 6	November	0 1	1 0
June	0 6	0 6	4 1	December	0 0	2 3
				Yearly average	0 6	1 0

The number of groups in the northern hemisphere belonging to the old cycle decreased from 34 in 1933 to 11 in 1934; in the southern hemisphere, from 7 to 3. The number of groups in the northern hemisphere belonging to the new cycle increased from 1 in 1933 to 17 in 1934; in the southern hemisphere, from 1 to 35. In low latitudes, where the spots of the old cycle occurred, the northern hemisphere was the more active, as in 1933. In high latitudes, where the spots of the new cycle occurred, the southern hemisphere was the more active. The mean distance of the low-latitude spots from the equator decreased from 8.1 in 1933 to 3.3 in 1934. In 1934 the mean distance of the high-latitude spots from the equator was 25.4.

SUN-SPOT POLARITIES

The accompanying table indicates the numbers of groups of spots classified from July 1934 to July 1935. "Regular" groups of the new cycle in the northern hemisphere are those in which the preceding spot had N (north-seeking),

Hemisphere	Polarity					
	Regular		Irregular		Unclassified	
	Old cycle	New cycle	Old cycle	New cycle	Old cycle	New cycle
North	7	25	0	3	1	3
South...	2	58	0	0	0	9
Whole sun	9	83	0	3	1	12

or positive, polarity and the following spot S polarity. In the southern hemisphere these polarities are reversed. In the old cycle, "regular" groups are those in which the distribution of magnetic polarities is opposite to that just described for the new cycle.

SOLAR ROTATION

A long series of spectrographic determinations of the equatorial rotation of the sun was begun by St. John in 1914. Since 1932 the spectrograms for the continuance of this program have been made by Nicholson and Richardson, the measurements by E. F. Adams.

An investigation of the effect of scattered light on the solar-rotation values was started in 1932. Plates taken with the rotation apparatus in the usual way consist of narrow strips of spectra a millimeter apart produced by simultaneous exposures on the center and on points about 14" inside the east and west limbs of the sun. With this arrangement diffracted light from each spectrum is superposed on the adjacent spectra, which should make the measured displacements of the lines too small. To avoid this complication the east and west limbs were photographed separately with greater distance between the spectra on the plate. The mean of twenty exposures made in this way gave 2.014 km/sec., while exposures taken in the regular manner gave

1.987 km/sec. The difference of 0.027 km/sec. indicates that the rotation values from the regular program should be increased by about 1.5 per cent to correct for the effect of superposed diffracted light.

In addition, since 1933 exposures have also been made directly upon the slit, which was set about 2/3 inside the limb to reduce the effect of scattered light in the optical system. Rotation values derived from these direct exposures are consistently higher than those obtained from exposures made with the regular apparatus. The mean values are (number of exposures in parentheses):

Year	With Rotation Apparatus	Direct Exposures
1932	1 99 (20)	
1933	1 98 (19)	2 05 (16)
1934	1 97 (16)	2 05 (11)

These results indicate that the values of the solar rotation determined at Mount Wilson since 1914 should be increased by about 4 per cent.

SOLAR ACTIVITY AND TERRESTRIAL MAGNETIC DISTURBANCES

The hydrogen flocculi recorded on the Mount Wilson daily spectroheliograms from January 1917 to March 1935 have been catalogued by Richardson. The intensity of the bright hydrogen associated with all spot groups was estimated on a scale of 0 to 5, while the dark markings were classified as small, medium, large and very large. Exceptional disturbances, such as the sudden appearance or disappearance of intensely bright hydrogen, and cases of bright hydrogen appearing where no sun-spot is visible were also noted. Of special interest in connection with the dark hydrogen is the disappearance of large prominences from one day to the next and the peculiar formations that prominences sometimes assume.

Weights were assigned inversely proportional to the frequency of the hydrogen flocculi, thus emphasizing the very bright flocculi and large prominences, which presumably should be the most effective in producing terrestrial magnetic disturbances. Graphs constructed from these data show the variations in the bright and dark hydrogen flocculi during the last eighteen years. Comparison with the curves for terrestrial magnetic activity, available only to December 1930, and for relative sun-spot numbers shows that, in its main features, the curve for dark hydrogen resembles the curve of terrestrial magnetism more closely than that of either the bright hydrogen or the relative sun-spot numbers. This resemblance is increased by using only large and very large dark hydrogen markings in forming the curve. None of the curves agrees with the terrestrial magnetic activity when only short-period fluctuations are compared.

A graph of the intensity of bright hydrogen flocculi per sun-spot group during the last eighteen years shows no evidence of the eleven-year cycle and is fairly constant throughout the entire range. Apparently the hydrogen flocculi associated with sun-spots are, on the average, just as intense at sun-spot minimum as at maximum.

INTEGRATED SPECTRUM OF THE SOLAR DISK

The study of the infra-red solar spectrum has been continued by Babcock with special attention to the improvement of the scale of wave-lengths, the

extension of the observations still farther beyond the red, the estimation of intensities, and the identification of the solar lines. After adding a few observations with the interferometer and refining some of the earlier reductions, a list of 263 selected lines most suitable for use as standards was supplied for the Report of Commission 14 of the International Astronomical Union. Comparison with a preliminary list prepared three years ago shows only small changes. The new list extends from $\lambda 7050$ to $\lambda 12425$ and, when tested by several applications of the combination principle, appears to be self-consistent and correctly related to the scale already adopted in the visual region. Details are given in a *Contribution* now nearly ready for publication.

New sensitizers have so extended the spectral region within reach of photographic observation that useful measurements of the solar spectrum are now being made beyond $\lambda 13500$. Considerable difficulty is met in this region, owing to the presence of a prominent absorption band of terrestrial water-vapor which obscures the solar detail.

Dr. Charlotte E. Moore of the Princeton Observatory spent two months at Pasadena in the study of our solar data. During that time and since her return to Princeton she has continued the estimation of the intensities of the spectral lines on Mount Wilson spectrograms. A fairly satisfactory method has been developed by which the intensities are expressed on an arbitrary scale definitely related to the Rowland scale. When complete, these results will enable Russell to proceed with a revision of the calibration of Rowland's scale and the resulting distribution of elements in the sun that he has undertaken. Miss Moore has also added numerous identifications to those known a year ago. For this work Rowland's method of coincidences has been amplified by the utilization of recent advances in the analysis of many of the atomic spectra.

The spectroscopic evidence for the presence of sulphur in the sun has been augmented, and the presence of phosphorus has been established. New series lines of magnesium not yet found in the laboratory have been clearly brought out in the infra-red solar spectrum, and homologous lines of sodium and lithium are suspected. Three important absorption lines of the Paschen series in hydrogen, analogous to β , γ , δ of the Balmer series, are now available for study in the sun. Some of the strongest infra-red solar lines are due to silicon, and numerous strong iron lines have also been found.

SPECTRUM OF THE SOLAR CHROMOSPHERE

During the summer months Horace Babcock has continued his observations of the chromosphere with the 150-foot tower telescope and 75-foot spectrograph in the more accessible part of the infra-red region and in selected parts of the visual region. With the Snow telescope and a rapid concave-grating spectrograph, he has photographed some of the stronger emission lines as far as $\lambda 10938$, a line due to hydrogen. The outstanding chromospheric line thus far noted beyond $\lambda 10000$ is $\lambda 10830$, the first member of the principal series of helium triplets, whose well-known fine structure is unresolved in the chromosphere. The identification of the observed emission lines is not yet complete.

Thackeray has identified certain chromospheric lines occurring within the wide wings of the H and K lines of calcium with the ionized rare earths Nd and Ce. These lines extend, as emission lines, much farther into the disk than ordinary chromospheric lines because the weakened radiation within the wings of H and K results in a reduced absorption of the frequencies of the chromospheric lines. Absorption and emission by the rare-earth atoms seem to occur mainly above the layers of calcium that produce the wings of H and K.

ULTRA-VIOLET SOLAR RADIATION

The daily measurements by Pettit of the ratio of ultra-violet to green solar radiation on Mount Wilson are in their twelfth year. It now appears that a minimum value of this ratio amounting to 0.9 occurred during the summer of 1932. Except in three instances, the monthly means have been greater than unity since January 1933, with the highest value, 1.4, occurring in March 1935. There seems to be a tendency for the values still to increase, although it is too soon to be certain. The extensive measurements of the photographic records have been made by Miss Richmond.

The measurements of the energy-curve of the sun from $\lambda 0.7\mu$ into the ultra-violet at $\lambda 0.292\mu$ made on Mount Wilson in 1934 with the double quartz monochromator and thermopile have been reduced to a point where the trend of the results can be seen. The recent measurements check in considerable detail the work done at Tucson, Arizona, in May 1931 and, like those measurements, show that the ultra-violet energy in the sun itself is nearly constant from $\lambda 0.38\mu$ to $\lambda 0.325\mu$. The measurements were repeated during 1935 and will be repeated each year during the present sun-spot cycle.

These observations with the double quartz monochromator and vacuum thermopile give the energy in each 100 angstroms in the solar spectrum, and, of course, include the effect of all the absorption lines. It is desirable, however, to know also the form of the energy-curve in the continuous spectrum. Although it may be questioned whether any of the spaces between the thickly clustered lines in the ultra-violet are wholly free from absorption, it was thought worth while to determine ratios of the intensity between the lines to the average within each 100 Å as a means of reducing the thermopile curve to the continuous spectrum. A 21-foot concave grating of 8 inches aperture giving a bright first-order spectrum was set up on Mount Wilson and fed with light from the 12-inch siderostat. The problem has been attacked both photographically and photoelectrically: First, spectra were photographed as usual, but with a moving slit in order to integrate the lines; second, the instrument was used as a monochromator with both sodium and potassium quartz photoelectric cells and amplifiers, the amplifiers being constructed under the supervision of Whitford. With this equipment two methods have been used in both of which the spectral energy-curves within 100 Å were recorded photographically on a revolving drum: (a) The detailed spectral energy-curve within 100 Å was recorded and followed by a second record made with the first slit vibrating in order to integrate the lines: (b) A quartz monochromator with a salt-water prism was put in front of the first slit of the 21-foot concave to filter the light and thereby secure greater purity of spectrum; in this case the vibrating slit was not used and

the integration was done with a planimeter. Thus far the investigation has been carried only to $\lambda 0.36\mu$.

The contour of the K line which results directly from this work was sketched on the record and upon this same sketch were plotted the values obtained photographically by Thackeray with the same dispersion. The plot fits the photoelectric contour almost precisely except within one angstrom of the center of the line. It is expected that useful line contours will be obtained as a by-product of the investigation.

SOLAR SPECTROPHOTOMETRY

An improved high-dispersion monochromator has been devised by Dunham for trial in connection with the 30-foot grating spectrograph in the Snow telescope. A 15-foot focus off-axis concave mirror is used with a flint glass prism and plane mirror in a Littrow mounting. No change in focus is required in passing from one wave-length to another. A section of the spectrum of any extent down to 1A may be thrown into the main spectrograph, thus nearly eliminating the effects of scattered light. The combination is being used for photoelectric measurements of the shapes and intensities of solar absorption lines.

GENERAL MAGNETIC FIELD OF THE SUN

Several years ago, during a period of low solar activity, Hale undertook a study of the general magnetic field of the sun at the Solar Laboratory in Pasadena. The purpose was a new attack on the problem by methods partially enumerated in the Report for 1931-32.

This investigation, involving the use of a Zeiss microphotometer especially adapted for the measurement of new photographs taken with the 75-foot spectrograph, revealed once more the extreme difficulty of measuring the minute Zeeman displacements produced by the weak general magnetic field. Similar difficulties had been encountered in 1912, when the field was first detected after much strenuous work (*Mount Wilson Contributions*, Nos. 71, 72, and 148). The grain of the photographic plate, slight local distortions of the film, and the effect of occasional local magnetic fields complicate the problem, which is sufficiently difficult with any form of measuring device, even in the hands of the most skilful and experienced measurer. In the early work it was found that only about half the measurers could obtain consistent results. Most of the results were in agreement so far as the sign, distribution and order of magnitude of the field were concerned, but some showed considerable systematic differences in magnitude.

In a case of this kind it is essential to have many thousands of measures made by a number of different persons, using measuring machines of several types. In fact, after encountering many new obstacles, some of them due to defects in the spectrograph, Hale felt it advisable to remeasure many of the negatives used in the investigation of twenty years ago as a check on the previous conclusions.

The measuring devices used in this recent study have included the Zeiss microphotometer in several forms, adapted for both photographic and visual work; the original micrometer, with tipping plane-parallel glass plate, used for most of the earlier measures; a machine of the same type, with some

improvements due to Nicholson; a measuring machine of the Evershed type; and recently a new form of measuring machine, of a design chiefly due to Langer. Moreover, several series of direct measures have been made on selected lines in the second- and third-order spectra of the 75-foot spectrographs on Mount Wilson and in Pasadena. These visual measures have been made in part with the tipping plate and in part with the aid of photoelectric amplifiers, adapted for this purpose by Dunham, Stebbins and Whitford, who joined Strong and Hale in the observations. Furthermore, Mr. Evershed kindly measured some of the original negatives at his own observatory in England.

Confirmations of the polarity and order of magnitude of the general magnetic field on plates of the old series have been obtained by Strong (visual measures with a special form of Zeiss microphotometer), Evershed (with his own measuring machine), and Langer (with a tipping-plate micrometer). On the other hand, zero results have been obtained by Nicholson and E. F. Adams (with an improved form of tipping-plate micrometer) and W. Humason (with a Zeiss microphotometer). These zero results have not yet been explained.

The most recent measures, of a collection of plates of the old series, have just been completed by Langer, using a new form of combined measuring, recording and computing machine devised chiefly by himself. In addition to its advantage of great rapidity of operation, the use of this instrument frees the observer from any danger of possible bias. The results obtained from a total of about twenty-five thousand settings on the line $\lambda 5247.7$, on forty quarter-wave strips on twenty-three plates, unmistakably reveal the general magnetic field. Its polarity and order of magnitude are in good agreement with the early results.

As for the general magnetic field of the sun in 1933, a number of measures by Hale, made by Evershed's method on spectra photographed at the Solar Laboratory give zero results. The data, however, were insufficient in number and precision to yield safe conclusions. A series of differential measures made with the photoelectric amplifier seem, on the other hand, to show the existence of a weak field of the same polarity as previously observed.

LUNAR AND PLANETARY INVESTIGATIONS

Most of the spectroscopic observations of planets have been interrupted pending the reconstruction of the coude spectrograph. Wildt, however, has observed Jupiter and Saturn with a provisional arrangement of the coude instrument for the purpose of determining the intensity distribution of the continuous spectrum.

RADIATION FROM MERCURY

The measurements of radiation from the planet Mercury made by Pettit and Nicholson in 1923-25 have now been reduced in final form. Preliminary reductions showed the desirability of deferring the final solution until a catalogue of radiometric magnitudes of comparison stars had been compiled and a detailed study of the radiation of the moon had been made. The

twenty-six observations of Mercury taken between phase angles 32° and 126° were reduced to a common standard of radiometric magnitude and intensity of planetary heat and reflected light. The relations between phase angle and both planetary heat and reflected light outside the atmosphere are very much like those of the moon. The variation of planetary heat approximates that to be expected from a smooth slowly rotating black sphere.

The planetary heat from the whole planet at full phase, reduced with the distribution function found for the moon, yields a temperature of 600° K for the subsolar point of the planet at mean distance from the sun. A solar constant of $1.95 \text{ cal cm}^{-2} \text{ min}^{-1}$, corrected for the reflected sunlight as measured with the thermocouple and water cell, gives 617° K. For an adopted mean of 610° K, the resulting sub-solar temperature of Mercury at perihelion is 685° K and at aphelion 555° K.

MOON COMMITTEE

The Committee on Study of the Surface Features of the Moon is making an extended series of measurements of the changes which take place in the sun's rays on reflection by different parts of the moon's surface and by terrestrial materials. These changes are of two kinds: (a) the relative intensities of different wave-lengths of light are altered slightly on reflection, according to the nature of the reflecting materials (selective reflectivity); (b) plane-polarized light is introduced in amounts which differ with the character of the reflecting substance and with the angle between the impinging sun's rays and the reflected rays (phase angle). These changes are being measured by four independent methods: visual, photoelectric cell, thermoelement and polarization spectrograph. At present the visual method is receiving special attention in an effort to complete this part of the task during the construction of the new mounting for the 20-inch telescope which, it is expected, will be finished by the end of 1935. This instrument will then serve for detailed measurements by the three remaining methods. For the visual method a special eyepiece is used, which recently has been improved so that it is now possible to measure the percentage plane polarization in any beam of light with an accuracy of one-fifth of one per cent. Such measurements are being made in the light reflected by selected areas on the moon and by many different kinds of terrestrial materials, including rocks, minerals and other crystalline and amorphous substances.

The series of lunar photographs projected on globes $13\frac{3}{4}$ inches in diameter, begun two years ago, is being retaken under improved conditions. These miniature moons, which are angle true, aid the geologist in the physiographic study of the lunar surface.

GREEN AURORAL LINE

Whitford has studied the intensity of the green auroral line in the spectrum of the night sky as a function of zenith distance, with the object of finding the height of the glowing layer in the earth's atmosphere. Preliminary results indicate a height of 100 kilometers.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES

The measurement of trigonometric parallaxes has been continued by van Maanen, the total number of fields completed now being 406. During recent years the program has included a large number of faint stars having large proper motions, with the result that the parallaxes of 76 stars fainter than the tenth apparent magnitude have been added to the list of only 10 stars of this kind known in 1924. The absolute magnitudes of many of these are fainter than 10 on the photographic scale.

PROPER MOTIONS OF FAINT STARS

In duplicating early photographs taken at the 80-foot focus of the 60-inch telescope, several faint stars of large proper motion were found by van Maanen, the most interesting being a companion of ϵ Cygni, considerably fainter than the known optical companion. On the basis of 0'037 as the parallax of ϵ Cygni, the absolute magnitude of the new companion is 12.6.

In *Mount Wilson Contribution* No. 412, 1930, van Maanen and Willis gave the proper motions of 122 stars measured in 42 Selected Areas on 60-inch reflector plates taken at an interval of about 18 years. The investigation has been continued by Oosterhoff, who has measured proper motions for 705 stars in 91 additional Selected Areas. For the 6 remaining Areas of the program the late plates are still to be taken. Only those stars which showed unquestionable displacements in the stereocomparator were measured. Of the 705 new proper motions, 181 occur in the recently published *Radcliffe Catalogue*. The magnitudes of stars not appearing in the *Mount Wilson Catalogue* or in *Harvard Annals*, 101 are still to be determined. Although no special search was made for variables, 15 have been found during the work.

PHOTOMETRIC EXTENSION OF THE POLAR SEQUENCE

The determination of standard magnitudes of stars north of 80° declination by Seares and Miss Joyner in cooperation with Dr. F. E. Ross of the Yerkes Observatory is well advanced. The photographic magnitudes are complete except for occasional minor corrections for color arising from later revisions of the color index. About 300 provisional photovisual standards have been derived, and the photographs for the main photovisual program have been taken and measured. Color indices, approximate values at least, are now available for all the stars.

The data thus far accumulated have been published in mimeograph form (*Magnitudes and Colors of Stars North of 80°*) for use until the investigation is finished. The Catalogue includes 2269 stars, mostly brighter than photographic magnitude 11.5. The precision of the catalogue magnitudes (photographic values) varies greatly, and in general increases with the declination, at least up to 84° or 85° , because of more favorable observing conditions and increasing abundance of material. The number of plate-pairs per star ranges from one to seven. Between magnitudes 9 and 11 the probable error for a single plate-pair is ± 0.021 mag.; for all magnitudes together,

± 0.027 mag. The agreement with the international system in zero point, scale and color, so far as indicated by the 28 NPS stars included in the investigation, is satisfactory.

MAGNITUDES OF FAINT STARS IN SELECTED AREAS

Photographic magnitudes to 20.5, determined by Baade, are now available for Selected Areas 51, 57, 68 and 89. The results are to be considered provisional, however, until the direct intercomparisons of the different Areas have been reduced. Since S.A. 89 is well situated to serve as a standard region for a number of the nearest extra-galactic systems (Andromeda Nebula, M 33, NGC I 1613 and NGC 6822), the photovisual scale will also be established in this Area. Preliminary tests show that with the new Eastman IC plates this scale can be extended to magnitude 18.5 or even 19.0 without excessive exposure times.

Owing to unfavorable weather conditions during the spring, only a few plates have been obtained which test the photometric properties of the new aluminum coats on the mirrors. The total gain, regardless of spectral type, seems, however, to be of the order of 0.3 mag.

MAGNITUDE OF COMPANION OF SIRIUS

Observations of the companion of Sirius by Stebbins and Whitford with the photoelectric amplifier at the Cassegrain focus of the 100-inch telescope give a visual magnitude of 8.5, which is so near the Harvard value of 8.4, used by Eddington in calculating the extraordinary density of this body and by Adams in verifying the predicted relativity shift of the spectrum lines, that the numerical results and general conclusions already derived from the magnitude of the star need no revision.

OBSERVATIONS OF VARIABLE STARS

With the schraffierkassette at the 10-inch telescope Oosterhoff measured the photographic magnitudes of ζ Aurigæ during its 1934 eclipse (*Mount Wilson Contribution*, No. 518). Measures of XX Virginis indicate that the star is not an ordinary Cepheid, but of the RR Lyræ type, with the rather unusual period of 1.35 days. Measures of the short-period variable VV Puppis on two nights at the 60-inch telescope suggest that its mean brightness is subject to considerable fluctuation. Both at maximum and minimum, it was about a magnitude fainter than when previously measured by other observers.

With the 10-inch and 5-inch cameras, Oosterhoff is studying the variables brighter than magnitude 16 within a field $10^\circ \times 12^\circ$ in the Scutum Cloud. Through the courtesy of the Leiden Observatory, observations of this region were made with the Franklin-Adams telescope at Johannesburg on two nights during which measures were also in progress at Mount Wilson. Combination of these observations will considerably facilitate the determination of the periods of some of the stars. In addition, the fainter variables are being studied with the 60-inch telescope in two fields, each about two-thirds of a square degree. Although the fields are small, the intercomparison of five pairs of plates has revealed 14 variables.

VARIABLE STARS IN GLOBULAR CLUSTERS

M 5, 12, 53 and NGC 6171 were photographed by Oosterhoff at the Newtonian focus of the 60-inch telescope for a study of variable stars in the clusters. Several new variables were found in M 5 and M 53; none in M 12, and 8 in NGC 6171. For the last two clusters, however, only two pairs of plates have been compared.

COLORS OF GLOBULAR CLUSTERS

Stebbins and Whitford have completed measures of color of 69 globular clusters, practically all those visible from Mount Wilson. As already reported, globular clusters show distinctly the effect of selective absorption near the median plane of the galaxy, the color excess being most marked in the direction of the galactic center.

COLORS OF B-TYPE STARS

Stebbins and Whitford have nearly completed color measurements of about 400 B-type stars between magnitudes 7.5 and 10, in extension of similar work on the brighter B stars done at the Washburn Observatory. The photoelectric measurements of nebulae, globular clusters and B stars all contribute to the determination of interstellar absorption within the galaxy.

STELLAR INTERFEROMETER

Measures by Pease with the 50-foot interferometer indicate that the fringes for γ Aquilæ and ϵ Pegasi vanish at a mirror separation of about 55 feet, and for Antares at 11.5 feet. For the three stars we have therefore the accompanying results:

The diameters for Antares refer to the mean date August 10, 1934.

	Appt. Mag.	Spectrum	Parallax	Effective λ	Angular diameter	Linear diameter (Sun = 1)
γ Aquilæ . . .	2 8	K2	0".018	5615	0".0084	50
ϵ Pegasi . . .	2 5	K0	0 009	5600	0 0081	100
Antares . . .	1 22	M ₄ p	0 019	5750	0 041	233

DISTRIBUTION OF ABSOLUTE MAGNITUDES

Strömberg has developed a new method of determining statistically the distribution of absolute magnitudes in a group of stars of known apparent magnitude, radial velocity and proper motion. The method consists in projecting the velocities on several arbitrary axes fixed in direction. From the distribution of the reduced proper-motion components and the projected radial velocities, the distribution of the absolute magnitudes is derived for each of the arbitrarily chosen axes. Although more laborious, the method is superior to similar methods based on peculiar and parallactic motions. Applications to certain groups of stars are in progress.

FORMATION OF GALAXIES

Strömberg has continued his theoretical studies of the formation of stars from a primordial, viscous and compressible gas of very low density. The system of gas remaining after portions of large mass motion and molecules of high velocity have escaped, in general, contracts owing to dissipation of mechanical energy into heat and to radiation. The motions tend to become more and more regular because of very high kinematic viscosity of the gas, and, on the supposition that a final steady state of motion is approached, certain properties of this motion can be deduced. The scalar velocity is found to remain approximately constant. Gravitational energy is converted into heat and radiation, but the gross kinetic energy remains unchanged after the steady state has been reached. An explanation has for the first time been found for the observed connection between physical properties of stars and their motions. Most of the phenomena of the motions of the planets, asteroids and satellites in the solar system probably can also be explained in a way similar to that found for the stars in the galaxy. When angular momentum was imparted to them, the galaxy and the solar system were both much larger than at present. The high-velocity stars in the galaxy and the satellites in the solar system were formed outside the central plane before the motions had become circular.

PHOTOELECTRIC TESTS OF SEEING

A new application of the photoelectric amplifier by Stebbins and Whitford is the measurement of the rapid fluctuations of a star's light which accompany poor seeing. With additional stages giving a current amplification of 10^9 or more, it has been possible to follow the variations of first-magnitude stars with a 3-inch telescope. In conjunction with an oscillograph and photographic recorder, the amplifier will show variations in a star's light amounting to 50 per cent or more with frequencies up to 50 per second. It is hoped that the method can be developed to give an impersonal quantitative measure of the seeing at any time.

STELLAR SPECTROSCOPY

The efficiency of stellar spectrographic observation has been greatly enhanced by aluminizing the 60- and 100-inch mirrors. While no quantitative tests have been made, it is evident that in the usual photographic region the speed of the spectrographs has been materially increased relative to that attained with silvered mirrors used under average conditions of deterioration. In the ultra-violet region the spectra extend 200-300 Å farther toward shorter wave-lengths than those previously obtained under similar conditions with silvered mirrors.

The new mounting of the coude spectrograph was completed in December and has been successfully used for observations of Nova Herculis, the planets, and a number of stars. The design is such that by rotating the slit, either prismatic or grating spectrographs may be used. The slit and the optical parts of the 9- and 15-foot auto-collimating spectrographs and the plane grating are carried on a heavy inclined frame of structural steel, which floats on balls in such a way that no strain in the concrete pier can be transmitted to the spectrograph frame. The grating receives light from either of two

collimating mirrors having focal lengths of 115 and 184 inches, respectively, and mounted, along with the lenses for the Littrow spectrographs, on sliding carriages which may be brought easily into position as required. A Ross lens of 9-foot focus and its plateholder, and cameras of shorter focal length of the Schmidt type, are mounted for interchangeable use on a horizontal frame attached to the main frame. The temperature of the sensitive parts may be maintained within 0°02 C. The Pfund arc is so arranged that light from only the central part of the arc reaches the slit.

The other spectrographic equipment has been used without essential change. The observers have been Adams, Christie, Dunham, Humason, Joy, Merrill, Sanford, Strömberg and Wilson. For two stars of especial interest, ζ Aurigæ and Nova Herculis 1934, extended observing campaigns involving several observers have been carried through.

During the year 1369 stellar spectrograms have been obtained; 583 with one-prism, 231 with grating, 430 with three-prism ultra-violet, 66 with coudé, and 59 with low-dispersion spectrographs.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX

The catalogue containing the absolute visual magnitudes and parallaxes of 4179 stars, by Adams, Joy, Humason and Miss Brayton, has been published as *Mount Wilson Contribution*, No. 511. It includes nearly all the stars of types F, G, K and M, as well as a few A-type stars, that have been spectrographically observed at Mount Wilson during the last 25 years. The absolute magnitudes have been determined on a uniform system, based upon trigonometric parallaxes in the case of the dwarf stars and upon mean absolute magnitudes derived from parallactic and peculiar motions in the case of the giants. The probable error of a single determination of absolute magnitude derived from the internal agreement among 429 members of physical systems, such as binary stars and moving clusters, is ± 0.27 mag. The mean systematic differences calculated for the various spectral types show that the internal systematic errors between different reduction-curves are negligible.

A plot of the distribution of the absolute magnitudes of the catalogue against spectral type shows in a striking way the well-known sequences. The giant series and the main sequence are well defined. The scattering supergiants, the group of faint giants and the intermediate white dwarfs are suggestive of other sequences.

RADIAL VELOCITIES

Since the radial-velocity observations of Boss stars of late type are nearly complete, considerable attention has been given to the formulation of a new program of radial-velocity determinations. A list of about 1500 stars has been compiled, and observations have been begun. The new list comprises chiefly stars from Schlesinger's Catalogue of Bright Stars, stars in the Selected Areas, bright and faint components of binary systems, stars for which trigonometric parallaxes are available, members of moving clusters, and faint dwarf stars having large proper motions.

Unpublished radial-velocity determinations for about 600 stars are now in hand. Most of the measurements and reductions of spectrograms of the regular radial-velocity program have been carried on by Miss MacCormack, Christie and Wilson.

STELLAR SPECTROPHOTOMETRY

Dunham has obtained with the coudé spectrograph calibrated photometric plates of a limited number of bright stars for the determination of the shapes and intensities of absorption lines. Miss Carlson has helped with the measurements and has tabulated the theoretical intensities within a large number of multiplets that are astrophysically important.

ζ AURIGÆ

At the time of the eclipse of ζ Aurigæ in 1934, special effort was made to obtain as complete a spectrographic record as possible of the spectral changes occurring when the light of the smaller B-type companion passed through the atmosphere of the giant K-Type star. Christie and Wilson have measured the spectrograms and, with the aid of the spectrographic orbit of Harper and the photometric observations by Oosterhoff and by Huffer, have determined the elements of the system. (*Mount Wilson Contribution*, No. 519.)

From a number of microphotometric tracings of spectra of ζ Aurigæ taken during ingress and egress of the companion, they were able to devise a method whereby the effect of the light of the K star could be eliminated from the measures of the tracings. This process enabled them to measure the total absorption of the radiation which produces the continuous spectrum of the B star affected by the various elements in the atmosphere of the K star. From the changes noted, the relative numbers of atoms existing at different levels above the photosphere of the K star have been deduced.

No hypothesis thus far formulated accounts satisfactorily for the observed distribution of the elements. The measures of the hydrogen lines indicate that the shell of hydrogen surrounding the K-type star is of uniform density, but the distribution of the neutral metals apparently follows an exponential law.

NOVA HERCULIS 1934

Nearly 200 spectrograms of Nova Herculis 1934 were obtained with the cooperation of the various members of the observing staff. The first observations, made on the morning of December 15, showed bright bands of the expanding atmosphere which were flanked on the violet side by an α Cygni spectrum of absorption lines whose displacements corresponded to a velocity of -250 km./sec. This velocity decreased to -170 km./sec. on December 22, when the star reached its maximum apparent brightness of 1.3 mag. A few days later Wilson and Merrill discovered that the violet cyanogen bands, which had not previously been observed in novæ, were present in considerable strength. Measures by Sanford served to identify many cyanogen features in the red and yellow regions of the spectrum as well. The displacement of the cyanogen spectrum was the same as that of a second absorption spectrum which appeared at about the same time. After a few days the cyanogen disappeared, but the new spectrum, which resembled that of ε Aurigæ, proved to be the chief absorption spectrum of the nova. The displacements of the sharp absorption components were accurately determined. The velocity given by the second component gradually increased from -265 km./sec. on December 23 to -390 km./sec. on March 26. Several additional components with greater displacements were also observed. About April 1 the bright-line spectrum of the nebular stage appeared.

Adams, Christie, Joy, Sanford and Wilson have made a preliminary examination of the spectrograms covering the blue and violet regions. On account of the high dispersion employed, the coudé plates, which were taken by Adams and Dunham, are especially valuable for the identification of lines and for velocity measures. Cassegrain grating spectrograms showing the region from $\lambda 5150$ to $\lambda 6550$ have been measured by Merrill. The chief dark lines within this region whose displacements have been studied in detail are those of Na I, O I, Si II, Sc II, Ti II, Fe II and Ba II. Bright lines of several elements, especially O I and Fe II, show progressive changes of structure of considerable interest.

R AQUARI

A study of the anomalous features associated with the spectrum of the long-period variable R Aquarii and their behavior during the interval 1919-1934 has been completed by Merrill (*Mount Wilson Contribution*, No. 513). The star appears single, but the spectroscopic observations indicate three light-sources, all variable, *viz.* a red long-period variable, type M7c; a gaseous nebula, type P; and a blue "companion," type Ofp or Bep. The features and cyclic changes of the M7c spectrum correspond in detail to those of typical long-period variables. The nebular lines were sometimes conspicuous, at other times practically absent. On two occasions the "companion" spectrum resembled that of the nucleus of a planetary nebula; at other times it was entirely different, with either permitted or forbidden lines of ionized iron predominant. The spectroscopic data make possible a partial analysis of the light-curve into two curves: one for the Me star, the other for the "companion." The behavior of the spectrum of R Aquarii is extraordinary and extremely puzzling, but remarkable similarities between some of its phases and the spectra of certain other variables suggest that phenomena of general astrophysical interest may lie back of the apparent anomalies.

The outer nebulosity surrounding R Aquarii is extremely faint, the brightest parts being at the intersections of two nebulous arcs approximately $40''$ preceding and following the variable. A single spectrogram obtained by Humason with the slit of the spectrograph extending through the intersection preceding the variable shows the following emission lines, with their intensities appended: $H\beta(5)$, $H\gamma(2)$, $H\delta(1)$. On the same date the intensities of these lines in the spectrum of R Aquarii itself were 2, 5 and 30, respectively.

CEPHEID AND ECLIPSING VARIABLES

Radial-velocity curves for RR Lyræ, FF Aquilæ and Y Ophiuchi have been determined by Sanford (*Mount Wilson Contributions*, Nos. 508-510). The center-of-mass velocity of FF Aquilæ evidently undergoes a long-period change somewhat resembling that of Polaris. The velocity-curve of Y Ophiuchi differs markedly from that found by Albrecht a quarter-century ago. The velocity range is greater and the eccentricity has increased. The curves of both stars differ from typical Cepheid velocity-curves in having rising branches that are steeper than the falling branches. The spectroscopic orbit and estimated dimensions of the eclipsing star W Ursæ Minoris have been determined by Joy and Professor O. L. Dustheimer of Baldwin-Wallace College (*Mount Wilson Contribution*, No. 521).

Spectroscopic observations of Cepheid variables in the southern Milky Way have been continued by Joy. The well-determined velocity-curves of the Cepheid program are now being prepared for publication.

A number of eclipsing stars are under observation by Joy and Sanford.

ABNORMAL DISPLACEMENTS OF LINES IN STELLAR SPECTRA

Adams and Miss MacCormack have published in *Mount Wilson Contribution*, No. 505, the results of measurement of certain lines on high-dispersion spectrograms of the very luminous stars β Orionis, α Cygni, α Orionis, α Scorpii, α Herculis, β Pegasi and ϵ Pegasi. The lines especially studied are D_1 and D_2 of Na I, H and K of Ca II, $\lambda 3944$ and $\lambda 3961$ of Al I, and certain strong lines of Si II. These lines agree in giving negative velocities which are systematically larger than those derived from the normal stellar lines. As the stars are relatively near, the effect of interstellar absorption should be small, and it seems likely that the dissymmetry and measured displacements are due to radial convection currents or to expanding gaseous envelopes surrounding the stars.

INTERSTELLAR LINES

Many spectrograms of O-, B- and A-type stars have been taken with the grating spectrograph in recent years by Merrill as a basis for study of the detached D lines of sodium, and with the prism spectrographs by Sanford for a similar study of the H and K lines of calcium. A detailed investigation of the displacements and intensities of these lines is under way. Of the new interstellar lines discovered by Merrill and reported last year, $\lambda 5780$, 5796 and 6284 have been observed in the spectroscopic binary HD 224151 and found to remain stationary within the errors of measurement, while the stellar lines oscillate from -150 to $+132$ km./sec.

R- AND N-TYPE STARS

The program of radial-velocity determinations for stars of classes R and N has been closed, with only a few of those within reach still unobserved. The results have been compiled by Sanford and utilized to determine the solar motion, the galactic rotation and the direction of the galactic center (*Mount Wilson Contribution*, No. 525). The spectra of 17 N-type stars have been found to show exceptionally strong sodium lines, while for six others these lines are abnormally weak.

c STARS OF CLASSES B AND A

A list of 95 c stars of classes B and A has been compiled and published by Merrill in *Mount Wilson Contribution*, No. 512. The character of most of these stars has been either discovered or confirmed by observations made with slit spectrographs at Mount Wilson. The number having hydrogen emission is noteworthy. Because of their high luminosities (absolute magnitude about -5.0) and their great distances, c stars of early type should serve well for studies of galactic rotation, interstellar absorption and other important investigations. Preliminary experiments with the 10-inch telescope (exposures by Hendrix) indicate that such stars can be detected on objective-prism spectrograms by the anomalous intensities of the D lines.

RADIAL VELOCITIES OF GLOBULAR CLUSTERS

Humason has determined the radial velocities of three globular clusters by the measurement of their integrated spectra on low-dispersion spectrograms:

NGC 6440	-175 km./sec.	G3
6981	-180	G5
7006	-350	G3

MISCELLANEOUS INVESTIGATIONS

Adams and Humason have observed the spectra of the white dwarfs AC +70°8247 and Wolf 1346. They show features similar to those found in the companion of Sirius.

Merrill has continued his investigations of long-period variables. Radial velocities have been obtained for several stars hitherto unobserved, and the spectra of others of type Me have been photographed at minimum with low dispersion. Merrill has also continued his study of forbidden lines in stellar spectra.

Several spectroscopic binaries are under investigation by Christie and Sanford, among them the companion of Rigel.

Humason has observed with the low-dispersion spectrograph a number of faint dwarf stars having large proper motions. He has also obtained additional spectra of the expanding nebulosity emitted by Nova Persei 1901, taken with the slit of the spectrograph extending across the faintest part of the shell. The emission lines from this region are weak, however, and longer exposures will be necessary before any definite interpretation of the spectrum of this part of the shell can be made.

Humason and Baade have studied the large gaseous nebula in Cygnus, NGC 6960 and 6992. Radial velocities from the outer edges and near the center show that if the nebula is expanding, as the proper motions suggest, the rate of expansion is small. Including measures by Sanford made in 1924 and 1925, the mean velocity from the preceding edge is +14 km./sec.; from the following edge, +32 km./sec.; and from a region near the center, +50 km./sec. But since the spectra were obtained with a dispersion of 500Å per millimeter at H γ the uncertainty in the measures is of the same order as the differences observed. The result suggests that the parallax of the nebula is greater than 0".01.

The line $\lambda 4511$, which appears in emission in M- and S-type variables, was tentatively identified by Merrill and Joy in 1930 with a component of a resonance doublet of indium. Thackeray has studied the origin of this line and suggests that it is due to the coincidence of the other line of the indium doublet with H δ , the emission of H δ stimulating the indium atoms to radiate $\lambda 4511$ in a manner similar to the excitation of O III radiation by ionized helium in nebulae (*Mount Wilson Contribution*, No. 517).

Wildt has studied theoretically the influence of a temperature gradient on the dissociation and ionization equilibrium in stellar atmospheres.

NEBULAR INVESTIGATIONS

SURVEYS OF NEBULÆ

Two surveys of extra-galactic nebulae have now been completed by Hubble which indicate the numbers of nebulae per unit area brighter than magnitudes 18.5 and 21.0, respectively. Analysis of the five surveys now available gives the form of the relation between numbers of nebulae and limiting magnitudes. The empirical relation exhibits systematic deviations from that corresponding to an apparent uniform distribution of nebulae in space which are provisionally attributed to the effect of red-shift on apparent luminosity. The study of these results, which bear upon the interpretation of the red-shift, has led to an extensive review of all available data concerning the distances and velocities and the luminosity function of nebulae, and to revisions of the numerical quantities involved. Publication has been delayed pending the completion of a joint investigation by Hubble and Dr. R. C. Tolman of the California Institute of Technology on the bearing of these results on the theory of the expanding universe.

CLUSTER OF NEBULÆ IN CYGNUS

A new cluster of nebulae in low latitude has been found by Baade on photographs of NGC 6992. The position for 1930 is R.A. $20^{\text{h}} 55^{\text{m}} 7^{\text{s}}$, Dec. $+31^{\circ} 7'$; galactic longitude 43° , latitude -10° . The cluster consists of about 100 nebulae, 70 of which are situated within a circle of $16'$ diameter. The low surface brightness of the nebulae suggests that absorption affects the field.

COLORS AND INTEGRATED MAGNITUDES OF NEBULÆ

Integrated magnitudes of all extra-galactic systems in which supernovae have appeared have been determined by Baade with the schrafferkassette at the 10-inch refractor or by means of intra-focal images with the 5-inch Ross camera. The results are in good agreement with those obtained photoelectrically by Stebbins and Whitford, who have derived magnitudes and colors for more than 100 of these objects. The photoelectric cell gives precise measurements of the integrated light, and hence is invaluable as a check on the photographic determinations of brightness and the inferred distances of nebulae. The dispersion of color in extra-galactic nebulae is greater than in globular clusters; nevertheless, the nebulae give additional evidence on the absorption of light in our own galaxy.

MASS OF THE VIRGO CLUSTER

From the radial velocities obtained by Humason and Smith and by Slipher of the Lowell Observatory for thirty members of the Virgo cluster, Smith has derived some of the physical characteristics of the cluster. Comparison of the velocities of faint and bright members of the cluster shows that the radial velocity of a nebula does not depend on its magnitude. Since difference in brightness implies a difference in mass, it follows that equipartition does not hold in the cluster. The distribution of the velocities in right ascension and in declination shows that the cluster is not in rotation and, further, that there is no central concentration of high velocities. This result is taken to

mean that the cluster is neither condensing nor breaking up, but is a fairly stable assemblage, more or less held together by its gravitational field.

From the observed distribution function for radial velocity, the distribution function of space velocities was derived. For an assumed distance of 2.2×10^6 parsecs, this function leads to a mass for the cluster equal to 2×10^{17} g. or $10^{11} \odot$. On the supposition that the cluster includes 500 nebulae, the mass per nebula is approximately $2 \times 10^{11} \odot$. While this value is far larger than Hubble's estimate of $10^9 \odot$ for an average nebula, the mean peculiar velocity of 500-600 km./sec. for nebulae in the cluster, as against 150 km./sec. for isolated nebulae, lends support to the high value here found. It is possible that both figures are correct, the difference representing a great mass of inter-nebular material within the cluster.

AN INTENSIVE STUDY OF M 32

An intensive study of M 32 has been undertaken by Smith as a beginning on the general problem of the structure of elliptical nebulae. Thus far the following results have been obtained: (1) A series of photographs through a large Wollaston prism showed no detectable polarization within $75''$ of the nucleus. (2) The existence of a definite nucleus which can be treated as a separate entity was established from photometric data, and observations were made to determine its angular diameter. Direct photography proving inadequate, interference methods were tried, but these yielded only a lower limit. Finally the value $0''.8 \pm 0''.1$ was obtained visually with the aid of a micrometer at the Newtonian focus of the 100-inch telescope. (3) The spectral type as determined from a series of low-dispersion spectrograms shows no variation along the major axis.

If we assume that M 32 is a gigantic globular star-cluster, the foregoing results lead to a value of 1.9×10^7 for the number of stars in the cluster and a central density of 8.8×10^6 stars/parsec³. The spectral type is dG3.

VARIABLE STARS IN NGC I 1613

The investigation of the variable stars in NGC I 1613 has been continued by Baade, and sufficient material will be available by the end of the 1935 season. Reliable photometric sequences have been established by intercomparisons with S.A. 68. For practically all the brighter variables (periods between 14 and 42 days) light-curves have already been obtained. The resulting provisional modulus of the system is close to 22.2 mag. Since the total apparent magnitude of NGC I 1613 is about 11.0, it is without doubt a system of low luminosity.

ANGULAR ROTATION OF SPIRAL NEBULAE

Measurements for the determination of angular rotations of four spiral nebulae, M 33, 51, 81 and 101, have been made by Hubble on several pairs of 60-inch reflector plates taken at intervals ranging up to 23 years. The angular displacements to be expected on these plates on the basis of van Maanen's early measures of these objects on plate-pairs of relatively short interval are 15 to 20 μ . The displacements actually found are of the order of the uncertainty of the data—about 1 μ on the average—and in the mean

for the four spirals are zero. A similar result is shown by measures of one pair of plates for M 81 by Nicholson and of two pairs for M 51 by Baade.

Recent measures by van Maanen of M 33 and M 74 on plates of excellent quality taken with the 100-inch telescope (42 feet focus) with nine years interval give a positive rotational displacement well in excess of the indicated probable errors. The value for M 33 is, however, a third less than that previously found by van Maanen. A few measures on 80-foot focus plates of M 33 and M 101 also show positive displacements, but with values which are also smaller than those obtained from early measures of 25-foot focus plates. Although several sources of possible systematic error have always been recognized, and in some cases certain kinds of systematic error are known to be present, none of them explains satisfactorily the persistence of the positive sign of the angular displacements shown by van Maanen's measures.

An independent analysis by Seares, involving reduction by a different method of most of the data now available, reveals local systematic displacements on some of the plates amounting to a few μ ; but these displacements, which seem to be of instrumental origin, are not rotational in character. The analysis confirms the zero result found by Hubble, Nicholson and Baade and shows that it can not be the consequence of a compensating systematic error which has neutralized a real rotational displacement. Although the anomaly of van Maanen's results remains unexplained, these recent investigations apparently remove the one outstanding discrepancy in the field of nebular research.

NEBULAR SPECTROSCOPY

Velocities of 19 extra-galactic nebulae have been obtained by Humason during the year. Among them is a value of +42,000 km./sec. from a single spectrogram of an object in the faint cluster Ursa Major 2. The velocities of +39,000 km./sec. and +24,000 km./sec., derived from the Boötes cluster and the cluster Gemini 1 and announced in last year's report, have now been confirmed by measures of additional spectrograms. The velocity from the Boötes cluster and the new velocity from Ursa Major 2 indicate that the velocity-distance relation is sensibly linear up to distances of the order of those of these clusters, which Hubble and Baade estimate at 70 million parsecs.

The velocities of 70 isolated nebulae brighter than apparent magnitude 13.0 are now known. When corrected for magnitude, solar motion and latitude they show no dependence on position in the sky. The early-type nebulae, E0 to E9 of Hubble's classification, are redder than the late-type spirals, Sc. The mean spectral types for four groups are:

Type	Spectrum	Number
E	G4.1	20
Sa	G3.2	17
Sb	G2.8	16
Sc	G0.6	17

Preliminary observations by Humason for measurements of rotation in NGC 3115 and NGC 4111 show inclined absorption lines, and with longer

exposures it should be possible to obtain spectra for both objects at a considerable distance from the nuclei.

A number of spectrograms of the elliptical nebulae NGC 3115, 4486, 4569 and 4648 extending into the violet to about 3100 Å have been obtained by Smith with the new quartz spectrograph and Schmidt camera. Each plate includes a series of spectra of a standard star as a means of comparing the energy distribution of the various objects. If these nebulae are assemblies of stars, the dominant spectral type would be expected to vary with the spectral region in which it is observed. Although the results are still incomplete, there is certainly no indication that the apparent spectral type becomes earlier as the region of shorter wave-lengths is approached; in fact the ultra-violet intensity, if anything, is lower than would be predicted from the usual classification of these objects. A certain amount of hydrogen absorption must be considered, however, and the final interpretation is not yet clear.

LABORATORY INVESTIGATIONS

ELECTRIC FURNACE SPECTRA

In continuing his study of rare-earth spectra, A. S. King has worked on the three elements in the middle of the group—samarium, europium and gadolinium—all three very rich in lines. The stronger lines of the ionized atom are in each case found in the solar spectrum; the absence from the sun of neutral lines of the rare earths, which are very strong in laboratory spectra, is, however, a remarkable feature. During the examination of samarium spectra it was found that the relative intensities of the neutral and ionized lines could be varied at will by changing the amount of the substance being vaporized, low vapor density giving the solar lines. This result suggests that in the sun, as on the earth, the abundance of the rare earths is very low, and that the consequent rarity of recombinations of ionized atoms prevents the appearance of neutral lines.

The temperature classification of samarium lines, the main results of which were reported last year, has been extended to a total of 4474, of which about 450 are low-temperature lines. Further examination of the complex structure of many samarium lines, supplemented by measurements of their components and considered in the light of Aston's recent discovery of seven isotopes for samarium, indicates that the complexities are probably a combined effect of isotope displacement and hyperfine structure in components belonging to the odd-numbered isotopes.

In preparation for the temperature classification of europium and gadolinium lines, suitable spectrograms were made for the range 2800 to 28000. Except for the ultra-violet section, the classification for europium, including more than 1200 lines, is complete, while from the gadolinium spectrum of nearly 3000 lines, those of low atomic levels, numbering 685, have been selected as a basis for the term analysis of neutral gadolinium.

Other work by King includes the selection of the low-temperature lines from furnace spectra of thulium for term analysis and the photography of furnace and arc spectra of titanium and vanadium in the infra-red as far as 10000 for comparisons with the sun-spot spectrum.

ANALYSIS OF RARE-EARTH SPECTRA

The rare earths (atomic numbers 57-71) have the most complicated of all spectra. Hund's theory indicates, however, that those at the beginning and end of the group should have simpler spectra than the others, and that even the complicated spectra of elements close to the middle of the group should have relatively simple portions. These predictions have been confirmed by the complete analysis by Russell of the spectra of lanthanum (57) and a large part of those of ytterbium (70) and lutecium (71). King's work on temperature classification has been of vital importance in these analyses and in recent work on the middle of the group.

Dr. Walter E. Albertson of the Massachusetts Institute of Technology has analyzed the main part of the spark spectrum of europium (63). He has also grouped about 450 low-temperature lines of samarium (62) into multiplets involving 175 different levels (including the most important low terms) and made a similar beginning on gadolinium (64). Albertson's work will be continued at the Observatory under a National Research Council fellowship. Russell and A. S. King have classified the most important lines of the europium arc.

These spectra are of considerable theoretical interest. Terms of multiplicity 9 are found in $\text{Sa } 1$ and $\text{Eu } 11$, and of multiplicity 10 in $\text{Eu } 1$. The highest value previously known was 8, in $\text{Mn } 1$ and $\text{Re } 1$; but 11 may be anticipated in $\text{Gd } 1$. The normal electron configurations of the neutral atoms are: Sa, f^6s^2 ; Eu, f^7s^2 ; Gd, f^7s^2d ; $\text{Yb}, f^{14}s^2$; $\text{Lu}, f^{14}s^2d$. Although the spectra are not yet completely analyzed, the temperature classification makes these results certain. Contrary to Bohr's original conjecture, three of the five configurations contain no d electron; and the similarity of the chemical properties of these elements, despite the differences in atomic structure, presents an interesting problem. The ionization potential of europium was found to be 5.64 volts.

SPECTRUM OF COBALT

R. B. King has measured the Zeeman patterns of 160 lines of neutral cobalt in addition to those reported last year; the total number now measured is 958. With the aid of these data and of unpublished results generously communicated by Dr. W. F. Meggers and Dr. Kevin Burns, Russell is engaged in an analysis of the arc spectrum. The spectrum has already been analyzed by others, but many strong lines remained unclassified and numerous energy levels were not collected into terms. The Zeeman data enable this to be done with assurance, and many new levels and terms have been added.

PHOTOGRAPHIC PHOTOMETRY OF IRON MULTIPLETS
IN FURNACE ABSORPTION SPECTRA

A method of measuring the relative intensities of absorption lines in complex spectra has been developed by R. B. King and A. S. King. The element to be studied is vaporized in the vacuum furnace, the absorption lines being obtained by passing a parallel beam of light from a Philips tungsten lamp operated at about 3100°C . through the tube and onto the slit of the 15-foot concave-grating spectrograph. With a small quantity of material in the furnace, the lines of the stronger class I multiplets appear faintly in absorp-

tion. The total absorption for very weak lines (below about 0.03 Å equivalent width for iron at 2100° C.) is dominated by the Doppler effect and is directly proportional to the number of atoms in the line of sight times the *f*-value for the line. Since for a given spectrogram the number of atoms enters as a constant, the measured total absorptions of lines on any one spectrogram having equivalent widths between 0.001 and 0.03 Å are proportional to their relative *f*-values when the latter have been corrected for the Boltzmann distribution which exists in the furnace. When the amount of absorbing vapor is increased, the stronger lines pass out of the part of the "curve of growth" dominated by the Doppler effect, and weaker lines then appear in this stage of development.

A large intensity range (about 3000 to 1 for iron at 2100° C.) is covered by the measurements made on lines appearing in the Doppler region for various amounts of absorbing vapor. Pressures of the order of 0.2 mm. of mercury are used in order to avoid the effects of collision broadening. Measurements of the relative *f*-values, with an average probable error less than 10 per cent, have been made on the lines of nine iron multiplets of classes I and II between 13650 and 14400.

VACUUM SPECTROGRAPH

Anderson has devoted the major part of his laboratory time to the vacuum spectrograph. The new aluminum casting has been found satisfactory, and a hypervac pump alone provides a vacuum sufficient for adjustments and tests of the spectrograph. Ordinary plates sensitized with oil have given usable spectrograms for zinc, copper and iron covering the region 12200 to 11300. For wave-lengths shorter than 11300, the spectrograms are too weak to be of service. This circumstance probably indicates that the grating ceases to reflect at about this point. For future work it will be desirable to install a new grating ruled especially for the short wave-length region.

After the preliminary tests had been completed it was thought desirable to increase the pumping speed. A glass diffusion pump using apiczon oil was accordingly assembled by Smith. When backed with the laboratory megavac pump, the diffusion pump easily reaches and maintains a vacuum better than 10^{-3} mm. of mercury, thus releasing the hypervac pump for other laboratory purposes.

The vacuum spark appears to work so well that a separate vacuum spark chamber has been designed and constructed for use as a source with the 15-foot concave-grating spectrograph. The object is to increase our knowledge of the high-ionization spectra of the elements in the visual and near ultra-violet regions.

RULING MACHINE

Babcock has studied in detail the origin of the residual errors in the new ruling machine. An application of the Michelson interferometer has led to the rejection of an experimental feature introduced into this machine, and in consequence the diamond carriage and its supports have been completely redesigned. Prall, working from his own drawings, has spent several months on the reconstruction. Study of the performance of the machine in the light of evidence afforded by gratings of excellent quality indicates that the spacing system needs only minor improvements to render it fully satisfactory.

A NEW TELESCOPE DRIVE

Smith has experimented with the vibrations of a stretched wire as a means of generating an alternating current which was amplified until sufficient power became available to run a small synchronous motor suitable for driving a telescope. The advantage of such a system is that while the rate can be kept very constant it can also be varied over a wide range by changing the tension of the wire. This feature makes possible a drive having a wide range in rate and, moreover, one such that the rate can be constantly corrected by the guiding operations.

SCHMIDT CAMERAS

The development of cameras with spherical mirrors and correcting plates at the center of curvature, similar to the telescope invented by Schmidt, has been continued. The first experimental camera of this type (30 inches focal length), which was made by Dunham last year, has been provided with a metal mounting and a new correcting plate of ultra-violet transmitting glass made by Hendrix. A camera of the same type with a focal length of 73 inches is under construction for the coude spectrograph. Both these cameras are designed to work off-axis so that the photographic plate is outside the incoming beam. A third camera, of 5 inches focal length and a focal ratio 1.75, has been made and tested with a temporary mounting in which a photographic plate 10 x 10 mm. is held centrally in the beam. Owing to the blind spot produced by the convex mirror at the top of the telescope tube, very little light is obstructed by the plate in the central position. The definition is very fine, and when the camera is used with the grating in the coude spectrograph, the speed is such that the spectrum of Nova Herculis has been recorded to $\lambda 8800$ and that of Arcturus to $\lambda 11000$.

VELOCITY OF LIGHT

The discussion of the measurements of the velocity of light made by Michelson, Pease and Pearson with the mile-long vacuum tube has been finished and the results have been published as *Mount Wilson Contribution*, No. 522. The seasonal means, the final mean velocity and the average deviations for a single determination are indicated by the accompanying table.

Series	Date	Number Determinations	Mean Velocity	Average Deviation
1- 54	1931, Feb. 19-July 14	493	km/sec. 290,770	km/sec. ± 12
55-110	1932, Mar. 3-May 13	753 5	299,780	11
111-158	1932, May 11-Aug. 4	742	299,771	9
159-233	1932, Dec. 3-1933, Feb. 27	897	299,775	± 11
1-233		2985 5	299,774	± 11

CONSTRUCTION AND MAINTENANCE

The opening of the connecting road between Mount Wilson and the Angeles Crest Highway on April 19 provides a new route between the Ob-

servatory and the Laboratories, Shops and Office in Pasadena. Although the distance is 11 miles greater, the driving time remains the same; but because of the width of the road and its easy grade the strain on motor equipment and on the driver is much lessened. The availability of the road during periods of heavy snowfall is still to be tested. The present ease of communication has greatly increased the number of transient visitors to the Observatory and raised questions as to the most effective method of handling large numbers of people in the domes of the 60-inch and 100-inch telescopes which are not yet satisfactorily answered.

No large construction has been undertaken during the year. The pier and foundation for the new mounting of the 20-inch telescope, and concrete steps, walk and retaining walls have been built on Mount Wilson; but the greater part of the time of A. N. Beebe, superintendent of construction, and of Sidney Jones, engineer on Mount Wilson, has been given to the maintenance of the buildings and equipment of the Observatory.

The instrument shop, under the direction of Alden F. Ayers, has met large demands in the construction of apparatus. The work of instrument design has remained in the charge of E. C. Nichols, assisted by H. S. Kinney. The most important items are the new coude spectrograph for the 100-inch telescope with provision for the use of either prisms or a grating with several cameras of different focal lengths; the new ruling machine; a thermoelectric photometer of the type designed by Dr. F. E. Ross of the Yerkes Observatory, which will greatly facilitate the measurement of photographs for the determination of magnitudes; and the revision of Cassegrain spectrograph No. VI. The repair and the modification of apparatus to meet the conditions of special observations are matters which each year require a considerable fraction of the time of the shop.

In the optical shop, John S. Dalton in charge, D. O. Hendrix, assistant, a large amount of work has been done in the construction of mirrors and correcting plates for Schmidt cameras. The largest of these are the two mirror strips, 7 inches wide, with foci of 32 and 73 inches cut from a 22-inch spherical mirror having both surfaces concave, which will be used in the large coude spectrograph. The correcting plates are of ultra-violet glass, 17 inches in diameter. Other noteworthy items are a 10-inch, 9° objective prism and the refiguring of the 12½-inch convex element of the Ross zero corrector to obtain a better distribution of spherical aberration over the field. In addition, the usual run of small optical parts passed through the shop, including concave and plane mirrors, lenses, stellite slit jaws, interferometer plates, and parts for the ultra-violet quartz spectrograph.

An important undertaking was the very successful coating of the large mirrors of the 60-inch and 100-inch telescopes with aluminum by Dr. John Strong of the California Institute of Technology, assisted by Dalton of the Observatory optical shop.

THE LIBRARY

During the year the library was increased by 194 volumes, 27 by gift, 82 by purchase, and 85 by binding; the total number is now 12,815, with about 10,000 pamphlets. In 1935 the library is receiving regularly 130 serial publications; of these 39 are sent as gifts or exchanges, as are also the publications of about 200 observatories and research institutions.

DIVISION OF PLANT BIOLOGY¹

H. A. SPOEHR, CHAIRMAN

For a number of years a major effort of the Division of Plant Biology has been directed to the study of the influence of climatic environment on the life and development of living organisms, particularly of plants. These investigations have been carried out by different groups, or sections, of the Division, which have attacked special features of the general problem, with different types of material, in different sections of Western United States, and with varying viewpoints and modes of approach. The expression of climate in terms of vegetation and plant societies, the effects of changes in the climatic complex, the possible periodicities of climatic changes, and the evidences of climatic changes throughout long periods of time are of fundamental significance for an understanding of the forms of plant life as these exist today. Conclusions regarding these phenomena may well contribute to a solution of the more immediate problems of climate in its bearing on agriculture and forestry. Many of these investigations of necessity involve long periods of observation and experiment, and it is largely through cumulative experience under a diversity of conditions that results of value can be obtained. Several of these projects are now being brought to a definite focus in an effort to give expression to general conclusions.

In 1922 an extensive experiment was undertaken by the late Dr. H. M. Hall to determine the extent to which taxonomic characters are modifiable through habitat factors. These experiments have been continued and somewhat extended since the death of Dr. Hall. The elaborate data resulting from these transplant experiments have been summarized through the year 1932, and the more general facts, which thus become evident, are being assembled for publication.

During the year an extended botanical exploration was carried out in Baja California by an expedition from the Desert Laboratory. The extreme aridity, which characterizes this peninsula in spite of the proximity of large bodies of water, and the many species of plants and types of vegetation, which are peculiar to it, make the study of this region an important part of the investigation of the great Sonoran Desert, which for some time has been a major program of the Desert Laboratory. Whereas on previous visits there had been no rain in several years, the year 1935, because of the unusually heavy rains, presented the most favorable opportunity in twelve years for the study of the vegetation of this region.

The penetration into the composition of any living organism or its processes has almost invariably revealed a vastly more complex situation than was expected at the outset. To this experience the study of the photosynthetic apparatus of plants is no exception. While the general outline of the chemistry of the green pigments, which are essential for photosynthesis, has been well established, the chemical structure and properties of the less obvious yellow pigments of leaves is still in progress of elucidation. The task has been greatly complicated by the fact that these latter components

¹ The Central Laboratory of this Division is located at Stanford University, California.

of the photosynthetic apparatus are far more numerous than was at first supposed, and the separation of the individuals has presented many difficulties. The necessity of contriving means of separating these individuals has, on the other hand, also led to a better understanding of their properties, so that this more intimate knowledge is serving as the basis for the development of theories concerning the rôle of these substances in the photosynthetic process.

PHOTOSYNTHESIS

By H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN AND H. W. MILNER

PLANT PIGMENTS

The fact has now been definitely established that the carotenoid pigments in leaves consist not of two or three chemical compounds, as was at first supposed, but of a large number of individual compounds, mostly mixtures of isomeres, of very similar chemical structure and differing only slightly in most of their physical and chemical properties. There is, however, much evidence from this and other fields of biochemistry that such apparently slight differences may nonetheless be of great significance in the functioning of these substances in the living organism, and it has seemed important to isolate these individual compounds and study their properties as far as is practicable. In order to isolate compounds of so nearly identical properties, it has been necessary to devise particular methods for their clean separation and to develop refined means for their identification. For the separation of mixtures into the individual component pigments, their adsorption on columns composed of substances such as magnesium oxide and calcium carbonate has still proved to be of great value, though more intimate study has revealed a number of limitations of the method as well as the special precautions which are essential to its successful use. For the identification of the different pigments, the most useful property is their spectral absorption; and here also a number of refinements have been found essential in order to obtain thoroughly reliable results.

The adsorption method has now been applied in this laboratory for the isolation of carotene from more than one hundred and fifty different natural sources, including a wide variety of plant materials and some of animal origin. In spite of the fact that many of these materials were rich in fats, waxes and terpenes, that is, in substances which occasion much difficulty in the isolation of the pure pigment, the method can be made to yield pure products, and no natural source has yet been found from which the carotene can not be isolated, provided, of course, that it is extractable from the natural source with organic solvents. The behavior of the pigments toward the adsorbent is very appreciably affected by the presence in the solution of other organic substances. Hydrocarbons and ketones do not affect appreciably the adsorption of the carotenes, but higher aliphatic alcohols, which often occur in natural products along with these pigments, cause a rapid elution of the carotenes from the adsorbent. It is essential, therefore, to separate as much as possible the pigments from the colorless constituents of the solution. This can in a measure be accomplished by the use of long adsorption columns, removing from time to time the upper portions of the adsorbent, which contain relatively high concentrations of colorless sub-

stances, and by the use of successive percolations. With this experience it has been possible to perfect the adsorption method so that the carotenes can be easily isolated from crude extracts of plant material. Purification can be accomplished by further adsorption, yielding a product with a minimum quantity of colorless impurities. The latter can finally be removed by the use of methods of crystallization from a variety of organic solvents.

The very diverse natural sources from which the carotenes have now been isolated in this laboratory have been found to contain the beta isomere as the principal constituent. Frequently α -carotene occurs with β -carotene, and very small amounts of strongly adsorbed and as yet unidentified carotenes are also present. The dodder, *Cuscuta salina*, has been found to be an unusually good source of γ -carotene. Pure, crystalline α -carotene has been isolated from the leaves of several plants and has been found to be identical with α -carotene from carrot roots and from palm oil. A carotene, less readily adsorbed than α -carotene and apparently identical with a similar carotene found in palm oil, has been isolated from the leaves of the so-called white carrot (var. White Belgian).

The positions of the pronounced spectral absorption bands of the carotenoids are characteristic of the individual pigments, and this property has been extensively used for their identification. The exact determination of the position of these absorption bands is of the utmost importance in connection with the determination of the purity of carotene preparations. This may be emphasized, for example, by the fact that the Committee of the Health Organization of the League of Nations on standardization of vitamine preparations has specified the maxima of the absorption bands of β -carotene to be used as a standard for vitamine research. But there still exists considerable disparity in the results obtained by different workers in regard to both the exact position and the height of the specific absorption curves of some of these compounds. The obvious desideratum is a thoroughly reliable spectrophotometric method for the analysis of carotenoid mixtures, but this, clearly, must await the exact determination of the positions of the maxima of the absorption bands of the individual pigments. A critical re-examination of the positions of the absorption bands of α -carotene, β -carotene and lycopene has been made by the use of different methods.

For this purpose all apparatus was subjected to rigorous test, and some improvements were made on the photoelectric spectrophotometer which made its use both more rapid and more reliable. Particular attention was given to determining that the apparatus gave a response directly proportional to the intensity of the light incident on the photoelectric cell, that all "false" light was eliminated from the monochromatic beam, the intensity of which was to be measured, and that results obtained for the absorption coefficients of a solution recommended for photometric work were in agreement with data previously reported. The standard solution used for this purpose was a mixture of equal molecular quantities of potassium chromate and copper sulphate in 2 N. ammonium hydroxide. This solution was shown to conform to Beer's law and almost perfectly to the absorption law for mixtures.

For the determination of the absorption maxima of the carotenes, three methods were used for comparison: spectrophotometric, spectroscopic and spectroscopic supplemented with a copper-ammonium filter. The discrepancies in the values for the maxima of the absorption bands of the carotenes reported by different workers appear to be due to differences in the methods which have been employed for making the measurements, although the real causes for these discrepancies have not as yet been discovered. The use of spectrophotometric methods yielded results of good agreement. On the other hand, visual observations with the spectroscope placed the absorption band, which is farthest toward the red, at wave-lengths slightly longer than those observed with the spectrophotometer. This slight shift is in all probability due to an optic-physiological effect caused by the contrast of rapidly changing intensities of light of different color across the field of vision. The introduction of a copper-ammonium filter sharpened the maxima considerably when viewed with spectroscope alone but shifted the position of the maximum of the absorption band, which is toward the red portion of the spectrum, very far toward the longer wave-lengths. In the case of β -carotene the shift was approximately 100 Ångström units. The results of these determinations are summarized in the accompanying table.

The absorption maxima of α -carotene and of β -carotene in carbon bisulphide solution observed by different methods

	α -carotene		β -carotene	
1. Spectroscope with copper-ammonium filter (visual)	512 8 m μ	478 9 m μ	522 3 m μ	488 1 m μ
2. Spectroscope (visual)	508 8	478 1	516 8	485.9
3. Spectrophotometer with copper-ammonium filter in both paths (visual)	507 2	476 5	513 3	485 1
4. Spectrophotometer (visual)	507 4	476 6	512 5	483 4
5. Photoelectric spectrophotometer	508	476	513	484

Redeterminations of the absorption coefficients of carefully purified preparations of α -carotene, β -carotene and lycopene, dissolved in 20 per cent ether in ethanol, were also made by means of the photoelectric spectrophotometer. The results obtained confirm the earlier determinations of the absorption coefficients of these pigments in solution in ether-ethanol and in ethanol. However, the results obtained with the pigments dissolved in carbon bisulphide are not in entire agreement with those of other workers. The causes for these differences have as yet not been discovered. The table on opposite page summarizes the results.

The complexities presented by the xanthophyll pigments are even greater than is the case with the carotenes. This is apparently associated with the fact that the xanthophylls contain in addition hydroxyl groups, the number of which may vary from one to six, and which materially affect the properties of these compounds. These pigments are moreover extraordinarily reactive with oxygen and with acids, so that particularly careful manipulation is essential in order to obtain consistent and reproducible results. They are universally present in green leaves in appreciable quan-

tity although, along with the carotenes, their presence is masked by the green of the chlorophylls.

The homogeneity of leaf xanthophyll has been a disputed question for many years, the opinions depending in a large measure upon the methods which have been employed for the isolation and separation of these pigments. In principle there have been two modes of approach to the problem; in one of these, conclusions concerning the composition of the leaf xanthophylls are based upon their extraction and partition with solvents by means of the classical methods of Willstätter and Stoll; in the other, the conclusions are based upon extraction of the total pigment mixture and resolution by means of the Twett chromatographic adsorption columns. The uncertainties of the first method have been primarily those of imperfect separation by means of partition in the different organic solvents used, resulting in the discarding of fractions containing xanthophylls of particular interest

Pigment	α -Carotene		β -Carotene		Lycopene		
Melting point . . .	187° (corr.)		184° (corr.)		174 5° (corr.)		
Solvent: 20 per cent ether in ethanol							
Absorption maxima, $m\mu$ Coefficient $\times 10^{-4}$.	476 12 96	448 14 13	480 11 90	453 13 44	504 16 34	473 18 00	446 11 99
Solvent. carbon bisulphide							
Absorption maxima, $m\mu$ Coefficient $\times 10^{-4}$. . .	503 9 87	476 10.80	513 9 33	484 10 40	545 12 32	507 13 43	478 9 04

and amounting to almost 30 per cent of the recoverable xanthophylls. The limitations of the adsorption method were essentially, that insufficient quantities for accurate chemical identification of the pigments could be obtained and that the process of adsorption might entail oxidation reactions of other destructive reactions of the pigments, which would give unreliable results.

During the last two years a careful reinvestigation of this entire situation has been undertaken on the basis of the past nine years' experience in the handling of these sensitive compounds. It is in a large measure owing to the remarkable adsorptive properties of the magnesia (No. 2641 of the California Chemical Company), its adaptability to a variety of needs, and to adequate supplies of different organic solvents, some of which have not before been used for this purpose, that it has been possible to carry out sufficiently large-scale experiments to overcome the shortcomings of both the methods mentioned. It has thus been possible to modify the Willstätter and Stoll method so as to yield the products which previously escaped attention, and to improve the adsorption method to yield sufficient amounts of pure pigments for identification by spectrophotometric and chemical

means. Needless to say, the details of manipulation are rather involved and can be only briefly summarized in the present report.

The dried, coarsely ground leaves are extracted with hot 99 per cent methanol, and the extract is concentrated to a small volume. This concentrate is diluted with an equal volume of ether and allowed to stand for two hours in order to permit a mass of viscous gums to separate. The solution of mixed pigments is then saponified with potassium hydroxide in methanol at room temperature and after the addition of ether is washed with a large quantity of water. The dried and concentrated ether solution is poured into petroleum ether to remove the carotenes. At this stage the xanthophyll crystals separate and can be filtered and washed with petroleum ether. They are again dissolved in dioxane and permitted to crystallize by the addition of petroleum ether.

This xanthophyll preparation can now be separated into its various components by passing a solution thereof in dichlorethane through a column of magnesia. There is thus formed a Tswett chromatogram which gives indication of the presence of at least fifteen different components. Some of these are, of course, present in very small amounts, but most of them have been isolated and some of their properties determined. The main portion, 50 to 60 per cent, proved to be lutein. Adjacent to the lutein adsorption band was one composed of zeaxanthin. This xanthophyll has never before been isolated from leaves. It has now been found in the leaves of carrots, miner's lettuce, filaree, squash, spinach, sunflower and barley. When long adsorption columns were used, another yellow band appeared between those of lutein and zeaxanthin from which a xanthophyll not previously known was isolated. This new xanthophyll proved to be optically inactive, as contrasted with lutein. It melts 5° to 8° higher than lutein and exhibits spectral absorption maxima about 20 Ångstrom units nearer the violet than those of lutein. This xanthophyll differed from both lutein and zeaxanthin in that its solution in ether produced a deep blue color when treated with concentrated hydrochloric acid. Provisionally this xanthophyll is called "isolutein."

Among the less definitely identified xanthophylls were pigments contained in three or four poorly defined bands on the adsorption column, which passed through ahead of the main portion of the xanthophylls. The pigments isolated from these bands resembled kryptoxanthin, a mono hydroxy xanthophyll, in respect to their distribution between methanol and petroleum ether, but their spectral absorption maxima were about 40 Ångstrom units nearer the violet than those of kryptoxanthin. A light yellow band, which separated into two bands upon continued washing of the column, appeared above the band containing zeaxanthin. The xanthophylls isolated from these two bands exhibited identical spectral absorption maxima (4510 and 4220 Å in ethanol). The xanthophyll from the lower band was dextro rotatory $[\alpha]_{D}^{25} = +75^{\circ}$, in chloroform, and that from the upper band was levo rotatory, $[\alpha]_{D}^{25} = -56^{\circ}$. Although the shape of the spectral absorption curves of these xanthophylls resembled flavoxanthin, a trihydroxy xanthophyll, they differed from this in other properties. These and other xanthophylls which have been isolated in sufficiently large amounts are still under investigation.

As has been stated, one of the most characteristic properties of these pigments, by means of which they can be identified, is the position and shape of their spectral absorption bands. It has been found, however, that great care must be exercised in making the measurements of these, because "isolutein" and the strongly adsorbed xanthophylls decomposed so rapidly in carbon bisulphide that their absorption spectra could not be determined accurately in this solvent. It was also observed that strongly adsorbed xanthophylls are adsorbed on the walls of glass vessels from a carbon bisulphide solution, which may also cause serious errors. These xanthophylls are, however, not adsorbed on glass from ethanol solution, nor do they undergo rapid decomposition in this solvent.

The demonstration of the heterogeneity of leaf xanthophyll and of the great differences in the light absorbing properties of the several constituents has an extremely important bearing upon most of the methods which have been used for the determination of xanthophyll. Many of these methods depend upon a comparison of the light absorbing power of the xanthophyll solution, whose concentration is to be determined, with that of a solution of xanthophyll of known concentration. An examination of the spectral absorption curves of the various xanthophylls which have been isolated has led to the conclusion that this method may result in errors of as much as 15 to 40 per cent, depending upon the nature of the solution used as a standard. This error may vary with the wave-length of light employed in the measurements and is independent of the accuracy of the method used for the determination of the light intensity.

By use of the adsorption method, the carotenoid pigments from a variety of flowers have also been prepared. It has been found very important to study the behavior of different pigment mixtures in order to identify the various individual pigments and correlate such findings with the large mass of observations recorded in the literature of this subject.

More exact examination has also been made of the pigments of the purple bacteria, *Spirillum rubrum*, which carries on a modified form of photosynthesis. From this organism has been isolated the brilliant purple pigment, spirilloxanthin, and its absorption curve determined in carbon bisulphide solution:

Wave-length of maxima, $m\mu$.	416	501	531	567
Molecular absorption coefficients $\times 10^{-4}$	3.35	10.82	14.66	11.97

An examination by means of adsorption columns of the pigments present in this organism has disclosed the presence of several pigments, which are still under investigation. The purple bacterium also contains a pigment analogous to chlorophyll and probably identical with bacterio-chlorophyll. This pigment is easily obtained in large yield through adsorption on sucrose, on which it is adsorbed in a blue zone. Its absorption spectrum in ether solution exhibits two well-defined absorption bands at 771 $m\mu$. and 576 $m\mu$.; the absorption coefficient of the former being 4.5 times larger than that of the latter. Weaker absorption bands in order of decreasing intensity were found at 710, 538 and 644 $m\mu$.

Dr. W. G. Leighton of Pomona College spent two months at the Central Laboratory of the Division engaged in a study of methods of determining absorption spectra in the ultra violet down to $\lambda 2000$ A. U.

With the object of working out the best conditions for the quantitative estimation of absorption coefficients, using the facilities available, a study was made of the advantages and limitations of each of three methods of spectrophotometry adapted to the small Hilger quartz spectrograph. These involved, respectively, (1) the conventional sector method employing a split beam, (2) the Zeiss stepfilter, with a single beam and a constant source, and (3) a series of neutral screens, with either single or split beam.

The screens, prepared by drilling thin sheet metal to give the desired transmissions, afforded a series of eight steps from 100 to 7 per cent transmission. These steps were calibrated by photoelectric cell and were also compared photographically with the calibrated filters. Transmissions calculated from dimensions also agreed fairly well with the calibrations.

The various steps of the Zeiss filter were calibrated at several wavelengths from $\lambda 6000$ to $\lambda 3000$ A. U., both by photoelectric cell and also by thermopile. An appreciable selectivity was noted, so this device may be used only over the range covered in the calibrations. With this arrangement a constant light source was essential. To obtain this constancy and also to secure the advantages of a continuum instead of a line source, a hydrogen discharge tube was set up with provision for following and controlling the intensity by means of a photoelectric cell and a hand-operated resistance. This source was used throughout the comparison of methods.

The three methods were tested by determining the absorption coefficients of solutions of potassium nitrate, potassium chromate, oxalic acid, uranium sulphate and uranium oxalate. The absorption coefficients were calculated from microphotometric tracings of the spectrograms. The results showed that for preliminary exploration of an unknown absorption spectrum, the split beam with either the sector method or screens is sufficiently accurate to give the general form of the absorption curve. The best results, both as to reproducibility and agreement with results in the literature, appear to be obtained with either the filter or the screen methods.

LEAF ENZYMES

It has now been established with a high degree of probability that some of the steps in the process of photosynthesis are enzymatic in nature. Although the process is exceedingly sensitive to poisons and mechanical disturbances of the photosynthetically active cells, repeated attempts have been made during the past fifty years to treat the leaf tissue by some method which, whilst not inactivating the enzymes, would at the same time actually kill the protoplasm. In these tests the liberation of oxygen on illumination of the plant material was used as being the most definite indication of photosynthetic activity. By the exceedingly sensitive test for oxygen through the use of luminous bacteria, it was shown by Molisch that leaves which have been killed through careful drying liberate oxygen on illumination. These findings have been confirmed, and it has also been shown that the liberation of oxygen is not due to infra-red rays, that is, to a possible liberation of

loosely bound oxygen through increase of temperature of the killed leaf material. The structure of the photosynthetic apparatus is apparently very sensitive to disturbance, for all other methods of killing the leaves, including freezing and a variety of narcotics, yielded material which was wholly inactive when tested with the bacterium method. Moreover, the quantities of oxygen which are liberated on the illumination of leaves killed by drying is exceedingly small. This was demonstrated by the use of a chemical method of determining the oxygen dissolved in water. This method was sensitive to 0.0002 mgm. of oxygen. Not the slightest trace of photosynthetic activity could be detected by this method in killed plant material when this was exposed to various intensities of illumination.

CARBOHYDRATES

In a great many plants the process of photosynthesis results in the accumulation of starch in the leaves. Although starch has been very thoroughly investigated by chemical and physical means, the source of this has almost exclusively been the storage organs of plants, such as seeds, tubers and roots, and very little is known concerning the so-called autochthonous starch, which accumulates in leaves as the direct result of photosynthesis.

The isolation of leaf starch presents difficulties because of the presence in leaves of a mixture of material of similar nature, from which the starch must be separated in order to obtain a pure product. A method for accomplishing this has been developed, which is based upon the fact that when a solution of starch is subjected to low temperature for some time, the starch is precipitated out of solution. By means of this process, known as retrogradation, it has been possible to isolate about 85 per cent of the starch contained in leaves of various species of plants and to study the chemical composition of this leaf starch. For most preparative purposes, a temperature of -8° to -10° , at which the starch solutions, extracted from the leaves, are frozen, yields satisfactory products. The leaf starches which have thus far been examined, from eight widely different species, have been found to be of the same general composition as the starch from other sources and are composed entirely of glucose units.

THE CHEMISTRY OF WOOD

The cooperative investigations of Professors Ernest Anderson and I. W. Bailey (Year Book No. 33, 182-183) have demonstrated that the pectic substances present in the primary walls and middle lamella of the cambial region are not completely transformed into, or replaced by, lignin during tissue differentiation. These substances are carried over into the mature wood, but their characteristic solubilities and other properties are masked by intense lignification. It is possible by carefully controlled delignification of wood to extract the pectic compounds in sufficient quantities for accurate chemical analyses.

Uronic-containing hemicelluloses occur in the secondary walls of the cells in wood. The solubilities of such substances are also modified by intense lignification, and delignification of wood is commonly essential for their complete extraction. The percentage of pectic compounds in mature wood is

much lower than that of the hemicelluloses, not because pectic substances are transformed into hemicelluloses or lignin during tissue differentiation, but owing to the fact that the volume of primary walls and middle lamella is much lower than that of the relatively thick secondary walls.

Not only do the percentages of pectic compounds and hemicelluloses vary in different parts of a tree and in plants of different systematic affinities depending upon a wide range of histological and other biological variables, but also the percentages of lignin, phenolic compounds, terpenes, and many other substances which seriously interfere with standard procedures for the extraction and analysis of polyuronides.

Professors Anderson and Bailey are now engaged in a comprehensive reconnaissance of different types of woods, not only to secure more specific and reliable data concerning the numerous biological variables, but also for the purpose of finding the most favorable material for detailed chemical analyses. It is evident that chemical methods for analyzing wood must be modified in accordance with variations in the biological variables. No single set of standardized and stereotyped techniques can be used without modification in the study of different woods.

During the past year Dr. Anderson has converted the pectic substance obtained from the cambium-phloem and sapwood of the black locust into calcium pectate, which was found to be identical with calcium pectate prepared from citrus and apple pectin. He has also isolated this material from lemon wood and has obtained evidence of its presence in spruce wood.

Professor Anderson has continued the examination of the two hemicelluloses obtained from the sapwood of black locust. They appear to differ merely in the number of molecules of sugar combined with a single molecule of uronic acid. He has isolated two similar hemicelluloses from the cambium-phloem and the heartwood of black locust. Whether or not these are identical with the hemicelluloses from the sapwood has not yet been determined. Determinations are being made of the amount of uronic acid present in a great variety of woods. While the data are not yet sufficiently complete to draw definite conclusions, the woods so far examined vary in their uronic acid content from approximately 2.5 per cent to approximately 6 per cent.

INVESTIGATIONS ON THE CAMBIUM AND ITS DERIVATIVE TISSUES

THE VISIBLE STRUCTURE OF THE SECONDARY WALL AND ITS SIGNIFICANCE IN PHYSICAL AND CHEMICAL INVESTIGATIONS OF TRACHEARY CELLS AND FIBERS, BY I. W. BAILEY AND THOMAS KERR

An extensive survey of a wide range of gymnosperms and angiosperms has shown that the structural pattern of the secondary wall is clearly visible in the large fiber-tracheids and libriform fibers of various dicotyledons.

By using untreated sections of such cells as controls, it is possible to observe the exact effects of specific chemical and mechanical treatments upon normal structures, and thus to extend the scope of investigation to cover a wide range of less favorable material.

The cellulosic matrix of the swollen secondary wall of cotton, as of normal tracheids, fiber-tracheids and libriform fibers, is an extremely heterogeneous

but firmly coherent structure, the finer details of which grade down to the limits of microscopic visibility.

There is no reliable evidence that the matrix is composed of discrete entities of visible size—*e.g.* elementary fibrils, dermatosomes, ellipsoidal bodies, etc.—that are bound together by non-cellulosic material. On the contrary, our data demonstrate that such putative entities actually are heterogeneous fragments that are shredded or disrupted from an originally continuous and coherent matrix. If there are discontinuities in the structural pattern of the cellulose in normal tracheary cells, they are confined to the submicroscopic field, *e.g.* to the realm of micelles or molecular chains.

The visible structural pattern of the cellulosic matrix varies greatly in form and texture, not only in different plants, but also in homologous cells of the same plant, and even in different parts of the same cell.

There are at least two optically different elongated complexes of cellulose which may be segregated into radio-helical, radio-longitudinal, or concentric-longitudinal lamellæ, or into various radio-concentric patterns.

The orientation of the elongated complexes of the structural pattern fluctuates more or less in successively formed parts of the secondary wall. In the case of normal tracheids, fiber-tracheids, and libriform fibers, there are three layers due to varying orientations: narrow, inner and outer layers, in which the orientation is more nearly at right angles to the longitudinal axis of the cell, and a central layer of varying width, in which the orientation is parallel to this axis or does not deviate excessively from it.

"Lignin" and other non-cellulosic constituents may be deposited in the elongated, intercommunicating interstices of the cellulose matrix, thus resulting in two continuous interpenetrating systems. In heavily lignified forms, either system may be dissolved without seriously modifying the structural pattern of the remaining system. The purified cellulose and the "lignin" residue reveal positive and negative images of the original structural pattern.

Deviations from the typical 3-layered type of secondary wall are of not infrequent occurrence. Thus, many thick-walled libriform fibers and fiber-tracheids have no clearly differentiated inner layer, whereas others have more than three layers of varying "fibrillar" orientation.

Conspicuous discontinuities in the structural pattern of the cellulose commonly occur in the multiple-layered walls of so-called gelatinous fibers, in certain types of bast fibers, and in scleroids. They are due to narrow layers of truly isotropic material which contain little, if any, cellulose.

There are five different types of visible concentricities which occur in varying combinations and may be associated at times with radio-helical or radio-longitudinal lamellæ. Therefore, it is misleading and fruitless to attempt to homologize all types of fibers in a single structural model.

EXPERIMENTAL TAXONOMY

By JENS CLAUSEN, DAVID D. KECK AND WILLIAM M. HIESEY

The problems with which these investigations are concerned cover many phases of plant biology. This broad field of operations, in which species from widely separated plant families are employed, minimizes the dangers

of one-sided interpretations and ill-founded generalizations that result from too limited a viewpoint. The parallax method is followed, the problems being viewed from morphological, distributional, ecological, cytological and genetic angles with different investigators doing the viewing. In the crossing experiments, the diallel method is employed, each key type in culture being crossed with a number of other types to insure as perfect a check on the results as possible. In this age of specialization there is great need for biological experiments that not only examine the details but build upon broad foundations.

TRANSPLANT STUDIES

Since 1922, when active work was begun with transplants in the Sierra Nevada transect, California, data have accumulated which record many facts concerning the modifiability of taxonomic characters of plants when grown in different climatic complexes, represented by differences in altitude, light and moisture. The methods of experiment, and the facilities available for this work, have been described in previous Year Books (*cf.* Nos. 21: 342-3; 23: 257; 24: 314-5; 25: 343-6; 32: 195-6). Mr. Hiesey is now preparing a review of the results on these studies covering the period between 1922 and 1932, as carried out under the direction of the late Dr. H. M. Hall, which will appear shortly. To summarize here the more general facts which are evident from the experiments involving a large number of plants from different species and families:

1. Every transplant retained its individuality irrespective of the conditions of altitude, light and moisture to which it was transplanted. A few transplants exhibited quite spectacular changes in vegetative characters when grown at different altitudes, but these modifications never obscured the individuality of a plant.

2. Every transplant has a certain capacity for modification when grown at different altitudes, or under different conditions of light and moisture at the same altitude. These modifications vary with different species, races and even individuals of the same race. The order of magnitude of these modifications is so small that no confusion ordinarily is caused in the taxonomic placement of well-established species or varieties.

3. All indications point to these modifications as being temporary, reversible and quickly induced. Meristems developing under the changed environment seem immediately to give rise to organs with the modified characters. No evidence is on hand which suggests yearly cumulative effects on perennial transplants.

Systematic yearly records of transplant individuals growing at the Stanford, Mather and Timberline stations are being continued, and with the aid of printed forms, in a much more detailed manner than formerly. This becomes necessary to properly evaluate the significance of the minor modifications; to detect possible cumulative effects of transplanting in the course of a number of years; and to study more fully the seasonal reactions of races of the same species originally from different habitats when grown at the three transplant stations. An anatomical survey of the modifications found is now being made by Mr. Hiesey in the hope that some, at least, may be expressed in terms of tissue and cell structure. Dr. T. D. Mallery of the Desert

Laboratory is making preliminary cryoscopic determinations of osmotic values in divisions of individuals of selected races and genera growing at the three transplant stations.

Perhaps one of the most valuable results of the transplant work is the pointing out of the wealth of unsolved problems pertaining to the relation between plant characteristics and environment. This is especially evident in the case of species having natural races distributed at low, high, and intermediate elevations, the forms from the low and high altitudes being the most contrasting in appearance, while numerous intermediate forms occur at the middle elevations. Examples of such species include *Achillea millefolium*, *Artemisia vulgaris*, *Aster occidentalis*, *Potentilla glandulosa*, *P. gracilis*, and the forms of *Zauschneria*. Fundamental problems are thus suggested in the study of the anatomical and physiological differences between races in the same or in closely related species with the possibility of obtaining evidence on the interrelationships between plant structure and physiology on the one hand and natural selection and survival on the other. Such studies should preferably be carried out with the same individuals, i.e. clone members, whose reactions are being studied as transplants. Investigations of this type are now under consideration, with full recognition of the complexities involved, yet in the belief that such an attack, carefully planned and interpreted, will stimulate an illuminating field of investigation from a viewpoint heretofore largely neglected. The facilities provided at the Stanford, Mather and Timberline stations offer a most unique opportunity for such researches, because these may be carried on concurrently with the transplant investigations. Meanwhile, cytogenetic studies are being conducted on these same materials.

HERBARIUM STUDIES

During the latter part of 1934, Dr. Keck devoted most of his time to intensive morphological and distributional studies of all *Madinae* species in the herbaria of California. Four hitherto unrecognized rare species were discovered. These data, together with accumulated data from field, garden and cytogenetic studies formed the basis for a systematic paper on 25 species of the *Madinae* in which 14 systematic units were described as new. This was published in order that the new names and combinations could be freely used. From January 1 to March 20, 1935, Dr. Keck visited the larger herbaria in Mid-western and Eastern United States, studying and annotating the collections in preparation for the *Madinae* monograph. Also several sections of the genus *Penstemon* were critically studied, and type material of *Zauschneria* was examined.

FIELD STUDIES

Because of abundant Winter rains, the Spring of 1935 was extraordinarily advantageous for field studies, and much of the area from central Washington to southernmost California has been covered in four field trips. As a result it will be possible to have all the known Californian *Madinae* in culture next year. Apparently many species do not germinate during the dry years but appear in profusion in very favorable seasons. When these species are local or rare, they may be overlooked for years. Thus the new and rare

Layia munzii escaped discovery in the two previous dry years on the alkali flat which we were thoroughly investigating in our studies on the equally new and rare *Hemizonia halliana*. In 1935, colonies of this *Layia* covered acres and formed dense stands between the plants of the *Hemizonia*. This flat is the type locality of each of these neglected but characteristic *Madinæ* and, strangely enough, is located in the Inner Coast Range alongside a much traveled highway. Similarly, abundant material was collected of the interesting new species, *Layia leucopappa*, previously known only from a fragmentary individual in the herbarium of the California Academy of Sciences. This species is probably the most restricted endemic of any of the *Madinæ*. Field studies indicated that it occurred in dense stands in interrupted colonies where the exposure was suitable over an area 8 miles long on Tejon Ranch, Kern County. One new *Hemizonia* species, of the *Deinandra* section, was discovered near the mouth of Red Rock Canyon, Kern County, on the western edge of the Mohave Desert.

On field trips it has been found essential to carry materials for making cytological fixations. Often critical forms are met, lacking ripe seed that can be taken for propagation, but in which bud material is available for determination of the chromosome number. Twigs with flower-buds in the proper stage are sprinkled, placed in parchment bags numbered to correspond to the herbarium vouchers, and carried in the vasculum until evening when fixations are made at the over-night stop. Buds that were somewhat wilted at time of collection will revive under this treatment with consequent improvement in fixation. To place authentic specimens for comparison in the important herbaria of the world, 50 sheets of important types are collected for ultimate distribution. Many of these will represent the key types used in the cytogenetic experiments. Field collections, fixations and garden experiments are unified by a simple numbering system.

GARDEN STUDIES

Methods used in garden studies have been described in Year Book No. 32, 1933, pp. 192-193, and No. 33, 1934, pp. 173-176. Under uniform environment in the Central Garden at Stanford University, with competition eliminated by a spacing of one meter, height has proved to be a dependable, easily tabulated, and illustrative character of race difference in species of *Madia*.

Over 500 cultures of *Madinæ*, totaling more than 16,000 plants, new *Zauschneria* cultures of more than 5000 plants, the transplant plots, and other perennials filled the entire garden space of eight acres.

This year 94 new hybrid combinations of *Madinæ*, mainly interspecific and intersectional ones, were grown. These are in addition to 45 others, reported up to the end of 1934. All were tested for fertility under various conditions, and materials of them were fixed for cytological study.

The 94 new hybrids occur as follows:

<i>Lagophylla</i>	2	<i>Hemizonia</i> , sect. <i>Euhemizonia</i>	7
<i>Layia</i>	17	“ “ <i>Deinandra</i>	19
<i>Madia</i>	15	“ “ <i>Olocarpha</i>	9
<i>Calycadenia</i>	9	“ “ <i>Centromadia</i>	16

Hybrids have now been formed in all genera and sections of *Madinæ* with more than one species. In *Layia* the gap between the 7- and 8-chromosome species was bridged for the first time and with two different hybrids. A single culture (11 plants) of *Madia radiata* ($n = 8$) was grown in the garden in 1934, and the seeds from open pollination sown this spring. Of 66 plants germinated all were interspecific hybrids, namely, 62 hybrids with various races of *Madia elegans* ($n = 8$) and four with three subspecies of *Madia sativa* (all $n = 16$). In this case pollen of foreign species must outgrow the pollen of *M. radiata* in its own pistil.

One of the most vexing problems to modern biologists is the species problem, and the experiments were designed to yield positive or negative answers on it. The answers from field data, chromosome investigations, and some 40 hybridization experiments in the genus *Layia* are so convincing and clarifying that this genus appears to be a perfect class-room example for the purpose and is to be used as an illustration in a forthcoming paper on the species question. The experiments show clearly the reality of natural species but also that differences between species are of various magnitude requiring some gradations of our concepts that picture the situation. Another interesting problem related to the species question was the inheritance of self-fertility in hybrids between a self-sterile and a self-fertile species studied on F_2 of *Layia gaillardiioides* \times *hieracioides*.

MISCELLANEOUS INVESTIGATIONS

Because *Penstemon* species are difficult to retain in culture, it has been decided to combine only field, cytological, and herbarium studies in the treatment of this genus. Twenty-eight species were extensively studied, and, of the majority, field-fixations made during a trip to northern California, Oregon, and Washington. Dr. Keck is to treat this genus in Dr. Abrams' *Illustrated Flora of the Pacific States*.

The California species of *Viola* are equally difficult to cultivate at Stanford, so similar procedure to that in *Penstemon* is being followed. The group including *Viola purpurea*, *præmorsa* and *Nuttallii* has for many years been the despair of taxonomists. The distribution of forms with various chromosome numbers ($n = 6, 12, 18$, and 24) seems to follow certain geographic and altitudinal lines. Two striking hybrids between species of this group and *Viola douglasii* have been found in nature, the first spontaneous hybrids of the *Chamæmelanium* section. Dr. Clausen is cooperating with Mr. Milo S. Baker of Santa Rosa Junior College in the taxonomic study of the *Viola purpurea* group.

Complementing the endemic Western American groups of *Madinæ* and *Zauschneria*, races of the northern hemispheric *Achillea millefolium*, *Artemisia vulgaris* and *Potentilla rupestris* (= *glandulosa*) are being studied. Mr. Hiesey has entered upon detailed studies of selected races of *Artemisia vulgaris* from California, Alaska and Northern Europe.

Mr. Palmer Stockwell, who assisted in the cytogenetic investigations during the year, is applying the methods of experimental taxonomy in a study of two groups of Compositæ, the genus *Chænactis* and the maritime ecotypes of *Franseria*.

Mr. Stockwell has also published a paper on the cytology of some of the cacti. Chromosome numbers are given of eight species or forms of *Opuntia* and of nine species of the tribe *Cereceae*. Comparisons are drawn between the chromosome set-up of these two related groups. It is pointed out in this paper that the few data available point to a correlation between polyploidy and distribution or adaptation, both climatic and edaphic. Later studies are tending to confirm these speculations. The object of this work is to clarify the questions of distribution and phylogenetic position of the Cactaceae.

DESERT INVESTIGATIONS

BY FORREST SHIRLIVE AND T. D. MALLERY

Investigation of the arid environment and some of its characteristic plants has been carried on at the Desert Laboratory since its establishment. The objective of the work has been to secure an understanding of biological processes, in both the individual and the race, as they take place under conditions which limit normal freedom of development. Intensive work was limited for many years to the region immediately surrounding the laboratory. Results were then secured which are in part applicable to all arid regions and in part incomplete with respect to regions of still greater aridity. During the last three years an investigation of the Sonoran Desert region has been in progress, constituting an extension of certain aspects of the work to the entire biological province in which all of the earlier operations were conducted. The exploration of the larger area and the investigation of its climate, soils and plants is vitally dependent on the intensive local work done in the earlier years of the laboratory. Several pieces of such work are still in progress. The grounds of the laboratory are being used for the continuation of work on the yearly changes in composition of vegetation, on the growth and longevity of desert plants, and on soil conditions. As a result of the recent exploration of Sonora and Baja California, new work has been undertaken on living plants not found in the Tucson region. Such knowledge of the range and habitat of these plants as can be obtained in the field needs to be supplemented by a much more intimate acquaintance with their germination, establishment, growth and life history.

During the past year two longer expeditions have been made into parts of the Sonoran Desert not previously investigated; shorter trips have been made for the continuation of routine climatic observations; and considerable time has been given to the elaboration of the results of field work. Progress has been made in determining the areas occupied by the several types of vegetation, as well as in establishing more definitely the geographical ranges of important plants. Particular attention has been given to the study of a number of widely distributed plants in different parts of their ranges. They have been examined with reference to their habitat requirements, their rôle in the vegetation, their size, reproduction and establishment. Two of them are being investigated in detail with reference to the osmotic value of their leaf sap.

Through collaboration with the Dudley Herbarium of Stanford University, Dr. I. L. Wiggins has accompanied the field excursions and has made

large collections of herbarium material over regions in which little or no collecting had previously been done. The work undertaken by Dr. Wiggins toward the preparation of a flora of the Sonoran Desert region has made good progress during the year. The completion of his studies will provide the first taxonomic treatment of this region, except a small part of it lying in California, and will furnish an essential basis for all other botanical work in the area.

Mr. Jack Whitehead, Assistant Director of the Boyce Thompson Southwestern Arboretum, at Superior, Arizona, accompanied the last two expeditions and made collections of living material of cacti, yuccas, agaves, dudleyas and other plants difficult to press or to determine in the field. The cultivation and study of this material by Mr. Whitehead gives valuable aid in groups of plants which are important in the make-up of desert vegetation.

FIELD WORK

In September and October 1934 an expedition was made to the inner edge of the desert in northeastern Sonora in the drainages of the San Miguel, Sonora and Moctezuma Rivers. The boundary of the Sonoran Desert was established for a distance of approximately 300 miles from Magdalena to the confluence of the Moctezuma and Bavispe Rivers, which there unite to form the Yaqui. The mountainous region examined is one which offers many sharp contrasts in vegetation. Extremely arid slopes resemble those far to the west, while the vegetation of the larger valleys is mainly composed of plants which range to the northern edge of the Sonoran Desert. In small valleys leading southward, and free from cold air drainage, many subtropical plants were found and new limits established for their northward ranges.

The edge of the desert was crossed at a number of localities, and particular attention was given to the habitats in which desert plants reach their eastern limit and those in which plants of the grassland and oak regions make their first appearance. The complexity of the topography and variety of soil conditions were found to induce unusual situations, in strong contrast to the uniformity which exists on the plains of western Sonora. In the upper Moctezuma valley, slopes belonging to the desert grassland transition region lead down to the floor of the valley, on which there is typical desert. Open woodlands of evergreen oak are first encountered at elevations of 2500 to 3000 feet, which is 1500 feet below the lower limit of this type of vegetation along the northern edge of the desert in Arizona. At several places oaks and palms were found growing together. Many of the generalizations regarding the vertical limits of vegetation which have been based on work in southern Arizona are not applicable to northern Sonora. The principal rivers are not bordered by broad continuous valleys in the region traversed. The vegetation of the plains of western Sonora ascends the valleys only with frequent interruptions to its continuity and with the loss of many of its characteristic plants. The absence of *Larrea* is particularly noteworthy, as it penetrates very similar country in western Arizona.

The relation between the vegetation of lava fields and of adjacent outwash plains has been studied in several parts of the Sonoran Desert. Northeast of Batuc, the valley of the Moctezuma is crossed by an extensive out-

flow, on which the extremely rough surface is provided with pockets and veins of soil well protected from evaporation. The plant covering is much heavier on the lava than it is on the neighboring deep loam soil and includes a number of species of trees and shrubs of southern relationship. Here and in the small warm valleys are found the northernmost representatives of species which are common in the thorn-forest of southern Sonora and Sinaloa. This subtropical element is much more richly represented in northeastern Sonora than it is in the plains of western Sonora at the same latitude and at slightly lower altitude. Some of these forms are in cultivation at the Desert Laboratory with the object of determining whether moisture conditions or temperature conditions are responsible for the direction taken by their northernmost distributional movements.

In February and March 1935 an expedition was made to Baja California, in which the peninsula was traversed to the cape and crossed at five places in different latitudes. Unusually heavy rains made the season a very favorable one for the study of the vegetation and for collecting plants and also made the region present a sharp contrast to its condition at the time it was visited in 1934. There had been no previous investigation of the plant ecology of Baja California. The opportunity to visit the lowland parts of the entire peninsula at a time when all plants were in recognizable or collectable condition made it possible to secure a very satisfactory body of data on the composition and distribution of the types of vegetation as well as to delimit with some accuracy the poorly known geographical ranges of numerous plants. One of the objects of the visit was to determine the southern limit of the desert region, which is being investigated in conjunction with that on the mainland, and to examine the transition from desert to the subtropical thorn-forest, which has long been known to occupy a part of the cape district.

Baja California is noted for the large number of endemics in its flora, which accords with the almost insular isolation of its southern half. Certain forms confined to the peninsula, or rare elsewhere, are very important in the composition of the vegetation, including *Idria columnaris*, *Pachycormus discolor*, *Viscainoa geniculata*, *Yucca valida*, *Opuntia cholla*, *Fouquieria peninsularis*, *Agave nelsoni*, *Franseria magdalenæ* and several others. Another equally large group of species is common to Baja California and other parts of the Sonoran Desert, including *Cercidium microphyllum*, *Prosopis glandulosa*, *Olneya tesota*, *Fouquieria splendens*, *Pachycereus pringlei*, *Larrea tridentata*, *Atriplex polycarpa*, *Lycium californicum* and *Lemaireocereus thurberi*.

The vegetation of certain areas in central Baja California is given a unique physiognomy by reason of the abundance of some of the large endemics of unusual habit of growth. Other areas closely resemble localities in Arizona or Sonora by reason of the species which they have in common or by virtue of the close resemblance between certain peninsular endemics and related species of the mainland. The character of the vegetation is influenced primarily by latitude, altitude and proximity to the sea. The Gulf Coast is far more arid than the Pacific Coast as far south as lat. 28°. On going farther south there is an increasing similarity between the two coasts. In traversing the length of the peninsula, a continuous change in

the flora may be observed. Only on reaching the latitude of La Paz is the change somewhat more accentuated. Below 3000 feet there is no evidence of a vertical increase of rainfall. The plateaus and mesas of the central district are covered by a low and monotonous vegetation, in which the large endemics are scarce. The influences exerted on the vegetation by topographic site and character of the soil were found to be strong, as they are in all but the most extreme deserts.

ENVIRONMENTAL CONDITIONS

Certain physical features of the soil known to be of importance to plants have been under investigation for several years. The continuation of the work is yielding a knowledge of the seasonal march of these features, the variation of the march from year to year, and the weight of the influences exerted on it by other variables. These investigations are concerned with moisture content, temperature and soluble salt content.

Periodic determinations of moisture content to a depth of 12 feet have now been made in two types of soil for four years. The value of the continuation of this work is illustrated by the fact that only once in the four years has there been such a combination of conditions as to result in a profound and relatively rapid rise in the moisture at depths below 5 feet. On the soil which supports natural vegetation of high water requirement there are greater seasonal and annual fluctuations of moisture than occur in the soil which forms the general floor of the desert.

In connection with the study of the natural changes of moisture with time and depth, an experimental investigation has been made of the rate of approach to equilibrium in soil with initial differences in water content. This work indicates that there is a movement of moisture about half-way toward equilibrium in the first two months, and that even an approximation to equilibrium is not attained in two years under the conditions of the experiment. This work has been confirmed by the results of the periodic determinations under natural conditions. The prolonged maintenance of differences in moisture content helps to explain the ability of certain desert plants to maintain vegetative activity in seasons of unfavorable atmospheric conditions.

Work done several years ago on the habitat conditions of *Larrea* seemed to indicate that the local distribution of this shrub was controlled by the soluble salt content of the soil. Further work in other areas showed that this hypothesis is not tenable. An investigation was then begun to determine the range of soluble salt content in small areas and the amount of variation that might take place from season to season at the same spot and same depth. Determinations have been made by the soil bridge method at 6 depths in 15 spots within a small radius and have been repeated one year later. Another series of readings has been taken at 8 depths at two-week intervals in an area 150 meters square over a period of three years. These series of determinations show a wide range of salt content in closely adjacent bodies of soil and also show marked changes in the same spot from month to month and year to year. The data have been carefully studied by Mr. Turnage in the effort to discover any correlation that may exist

with rainfall, soil moisture, or other conditions that are known for the areas used. No clearly defined correlation has been found. Some of the series of readings have been taken in bodies of soil which are smaller than those occupied by the root systems of desert perennials. The results of the work show that no two parts of the root system of a large plant are functioning in soil of the same soluble salt content. In this case, as in many others that are known, substantial differences of environment exist within the space occupied by a single individual.

Work on the temperature of the soil has been continued, chiefly with reference to the 3-foot and 6-foot depths. This investigation is being pursued with the aim of studying the march and lag of soil temperature and the influences of air temperature, rainfall and soil moisture in determining the temperature and its seasonal behavior. Although a high daily range of air temperature is one of the universal characteristics of desert climate, the lower levels of the soil show variation which is little greater than that in humid regions.

Rainfall measurements in the Tucson region and in remoter parts of the Sonoran Desert were begun over ten years ago and are being continued by Dr. Mallery. There are 31 long-period rain gauges in operation, 12 of which are within 20 miles of the Desert Laboratory and 19 in the sparsely settled region between Tucson and the Gulf of California. Every year that these records are continued increases their value in connection with the study of plant distribution and activities. Each of the stations is visited twice a year, shortly after the close of the rainy periods. The seasonal maximum and minimum temperature is also being read at some of the rainfall stations.

PHYSIOLOGICAL BEHAVIOR OF DESERT PLANTS

Work begun two years ago on the seeding habits, germination and early growth of some of the dominant non-succulent perennials of the Sonoran Desert has been continued. Similar work done many years ago on perennials of the Tucson region was found to throw a great deal of light on the ecological relations of the plants. Present work is being done on plants of Sonora and Baja California, as well as on some local species not previously investigated. One of the most striking aspects of the work as far as it has progressed is the discovery of a great diversity of behavior in these features which are fundamental to the perpetuation of the species and the successful establishment of new individuals in favorable habitats.

Seedlings are being studied with reference to their rate of growth and the relative development of root and shoot, as well as to the early development of the distinctive features of leaf and shoot, which are found in so many desert plants. The 1935 expedition to Baja California proved to be a very favorable opportunity for observations on germination and the collecting of young and advanced seedlings.

Knowledge of the water relations of the shrub *Larrea* has been increased by the work on the osmotic value of the leaves, which has been carried on by Dr. Mallery. His determinations have covered both the seasonal and habitat differences in the Tucson region and furnish an index to the behavior of this wide-spread and characteristic desert plant. In connection

with the field work of the past year, Dr. Mallery secured a large number of samples of *Larrea* for osmotic value determinations, covering the geographical range of the shrub in Sonora and Baja California and representing the entire gamut of conditions in which it occurs. A parallel series of samples was taken in the same localities in Baja California from the shrub *Viscainoa*, which is wide-spread there and known from a few restricted localities in Sonora. Determination of the values of the samples taken in the spring of 1935 is still in progress. The results will be of interest in relation to *Larrea* and also with reference to the comparative behavior of the two shrubs, which belong to the same family but differ greatly in leaf size and in abundance.

ECOLOGY

ADAPTATION AND ORIGIN, BY F. E. CLEMENTS, F. L. LONG AND E. V. MARTIN

The experimental studies that deal with the modification of existing species and the production of new forms have been continued through the respective seasons at the Alpine Laboratory and the coastal laboratory at Santa Barbara. In consequence of a critical lack of rainfall, convergence and conversion have been somewhat less in evidence than normally, while modifications in response to drouth or shade have increased in number. As might be expected, the grasses have supplied the large majority of these, partly because of their more xeric nature, and partly on account of their more recent and multiform evolution. These changes lend further support to the thesis that evolution is essentially a continuing process and that new forms may be produced more or less at will within the limits of a species, as well as beyond, to close the gaps between related ones or to reintegrate the countless minor species of descriptive botany.

One of the most complete series of modifications was obtained with *Koeleria cristata* under four different habitats. In the watered sun-garden, the spikelets developed 3 fertile flowers; the native sun-form with rainfall alone bore 2 fertile and 1 vestigial floret; the half-shade lath-house produced 2-flowered spikelets, while drouth plants were reduced to one flower with a vestige. In the case of the hydric *Aira caespitosa*, flooding in the wet garden under protracted drouth resulted in progressive vivipary; in many spikelets only the terminal floret was modified, the stamens and pistil disappearing and the scales turning green. In the next stage, two florets became virescent, the leaf-like scales developing ligules, and in the final case all three were more or less changed, to the point where rootlets were readily formed at the base.

With *Trisetum spicatum*, the number of florets in the spikelet was shifted from three in the normal form to four in the sun-moist garden, and to two in the lath-house, while the related *T. montanum* of the spruce forest was converted into morphological *spicatum*, its probable ancestor. The spikelet of *Bouteloua gracilis* was much modified in a light intensity of 12 per cent at the Plains Garden, the two inflated sterile florets and tufts of basal hairs being reduced to the point of disappearance. The same degree of shade shortened the spikelet and lengthened the rudiment in *Calamagrostis purpurascens* so that they became equal instead of the latter being half as long, while drouth conditions diminished the spikelet by half and all but climi-

nated the rudiment. In *Elymus canadensis*, shade decreased the spikelets from 3-4 to 2 at a joint, the glumes narrowing to subulate; with *E. ambiguus*, the number was reduced from 2 to 1 by shade and raised to 3 by optimum water-content.

The most significant modifications in forbs were obtained with *Oxyria digyna* and *Typha angustifolia*. When grown in the full-shade habitat of the spruce forest, the stems of *Oxyria* stretched to 3-4 times the stature of the dwarf alpine form, the petioles and blades were equally enlarged, and the stamens were suppressed. Under intense competition in 2 inches of water, the stems and leaves of *Typha* were decreased to a third the usual size, and the pistillate inflorescence vanished completely in those individuals most suppressed.

Further attention has been paid to modifying the season of flowering and determining the factors concerned, and related studies have been initiated on the season of growth, perennation and changes in life-form. With respect to time of flowering, evidence is being drawn from four experimental sources, namely, length-of-day tents and lathhouses with reference to the influence of radiation, and transplant gardens and planting out of season to disclose the effect of temperature. These are supplemented by comprehensive field observations upon the appearance and abundance of winter annuals as responses to the conjunction of rains and temperature. All these methods have combined to reveal a wide range of adaptability in most of the species employed. The flowering of *Stipa* may be caused to vary as much as three or four months, and certain species may be forced to bloom two or three times during the year. The blossoming of alpine dwarfs may be hastened in proportion to decreasing altitude and increasing temperature; it is regularly two to three months earlier in the Plains Garden than on the summit of Pike's Peak, while at Santa Barbara it occurs in mid-winter. In *Viola cucullata*, the order of appearance of flowers and leaves has been reversed by a month or more, and *Geum album* has continued to bloom from early summer well into the next spring. With reference to growth-forms, an increasing number of annuals have come to function as perennials; some perennials have been led to maintain their aerial shoots through two or more seasons, and others have become shrubby in character, among them several grasses.

The study of the functional responses of transplanted or adapted species has not only contributed to the further understanding of adaptation as a process, but has also added to our knowledge of the particular function itself. Moreover, it has pointed the way to another basic correlation between morphological criteria and physical factors, and thus provides an additional approach to the interrelations of climate and climax. The chief methods to this end are the phytometer and the field ecostat, both of which have been considerably extended and improved during the year. A new form of the latter has been devised for use in the alpine tundra on Pike's Peak, where low soil temperatures exert their chief influence. This consists of metal chambers, 4 feet square, which are placed at the root level in the soil and permit cooling and heating, respectively, to the amount of 10 to 20 degrees or more.

Light-tents in the form of an arc have been designed to constitute ecostats in effect, since the air circulates so freely through them that temperature and humidity are not appreciably affected. The usual batteries of sunflower phytometers were installed under five such tents with the control in full sunlight, giving a series of light intensities of approximately 10, 20, 40, 60, 75 and 100 per cent. The ten replications of the experiment covered a wide range of weather conditions over a period of two years, but in all cases the relation between radiation intensity and transpiration rate was found to be linear within the limits of experimental error. The results of all series may be satisfactorily represented by equations of the type $T = b + mR$, where T is the transpiration rate, R the radiation intensity, b the intercept on the T axis, and m the slope of the straight line. It was found that b varied directly with the evaporating power of the air, and m inversely with the age of the plants. The fraction ascribable to the direct effect of radiation is given by the ratio $mR/(mR + b)$, and for plants in full sunlight was found to vary from 38 to 81 per cent, depending largely upon the evaporating power of the air.

The effect of wind upon the transpiration and growth of sunflowers has been further investigated, for the purpose of testing earlier findings as well as the results of others working with low velocities alone. Wind up to 2 mph caused an increase of about 35 per cent in transpiration, while higher velocities produced much greater water-loss, up to 140 per cent at 15 mph, but only for the relatively brief period before the stomata closed, after which the rates fell to only about 25 to 50 per cent more than in the control. With respect to different wind movements acting continuously for 6 to 7 weeks, four replications were in accord in showing that 5 mph has very little effect upon size or dry weight, while wind of 15 mph brings about marked dwarfing, the leaf-area dropping to a fourth of that of the control, the stem height to a half, and the dry weight to a third or less. These results are in harmony with the behavior of transplants in the dune garden and appear to furnish part of the explanation of the characteristic adaptation to such habitats.

Studies of the respective rôles of water and light in causing elongation and expansion have been continued by means of two series extending over a period of three months, one in autumn, the other in spring. The major objectives in these were the comparative response of the tissue systems in root, stem and leaf, and the effect upon floral development. In addition, new functional data in considerable amount were derived from an increase of the light values from four to six in number and the use of three sizes of containers, together with controls provided by free phytometers grown directly in the open soil.

CLIMATE, CLIMAX AND SUCCESSION, BY F. E. CLEMENTS AND E. S. CLEMENTS

In continuation of the research on the rainfall cycle, a complete compilation has been made of the plus and minus departures from the annual averages for all the states of the Union, from the beginning in 1876 through 1934. The study of these in relation to the sunspot cycle indicated that both maxima and minima had regularly coincided with deficient rainfall and

suggested a further correspondence between the latter and the rate of change in spot numbers during each phase, as well as with the intensity at a particular maximum. These and other indices warranted the assumption of supranormal precipitation on the Pacific Coast in 1934-35, an expectation that was verified by the outcome. The general agreement in direction of departure between this region and the Middle West was further thought to justify the prediction that the drouth would be broken by the middle of May and that the rainfall of the region as a whole would be above normal.

The consideration of climatic trends during the past two years has naturally revolved about drouth and flood. These not only appear to have a discernible relation to each other within the climatic cycle itself, but they are also causally connected through the part taken by vegetation. The latter is susceptible to much greater damage by fire or overgrazing during periods of drouth; its control of runoff is seriously diminished and floods ensue. In addition, the intensity and length of the recent drouth period were the greatest on record in this country and hence have afforded a unique opportunity to trace the effects upon the dominants and other species of the climax. While no species of importance is known to have been eliminated from a considerable area, many have suffered drastic reduction in abundance. In the prairie this has been most telling in the case of invaders from more humid districts, such as *Poa pratensis*, but it has also thrown the balance, temporarily at least, in favor of the deep-rooted *Andropogons*, the sod-forming *Agropyrum*s, and the xeric short-grasses in their competition with such bunch-grasses as *Stipa*, *Koeleria* and *Sporobolus*, as well as *Andropogon scoparius*. The toll taken in the more mesic consociation of the montane forest, that of *Pseudotsuga taxifolia*, was even more serious, 50 per cent of the seedlings of this dominant being killed in some areas, while certain forbs of the forest floor suffered a still higher mortality.

Because of the indicator significance of the climax and the application of these values to reconstruction projects, the structure of the grassland formation has received special attention. The associations primarily concerned are the mixed prairie of the Great Plains, the desert plains of the Southwest, and the bunch-grass hills of the Palouse, each of which corresponds to a particular prairie climate. Within each of these are a number of subclimates, the contiguous ones passing gradually into each other but for the most part possessing a distinctive impress of much significance for range rehabilitation, erosion control and the planting of wind-breaks. By far the best integrator of the several subclimates is the subdivision of the association, or faciation, and the recognition and delimitation of such indicator communities becomes a task of immediate practical as well as scientific importance. It promises to yield a much more accurate picture of climatic differences than any subjective system and to permit such a mapping of climates as is indispensable to the proper classification and utilization of land, whether under natural or cultural vegetation.

The application of ecological methods and principles to federal and state projects has been much extended and definitized in the course of the year. The exclosure system for range research, developed on the Santa Rita Reserve and employed there for two decades, is being utilized in the form of production and protection units for measuring the carrying capacity and

regeneration possibilities in the various districts of the Division of Grazing. From the nature of the projects, the most comprehensive application is being made by the Soil Conservation Service and the Forest Service in the control of erosion and floods, and the working plans of the great projects that deal with natural vegetation in the West rest squarely upon the synthesis of climax, climate, topography and soil that has been developed by ecological research. The dramatic challenge of wind erosion as a consequence of denudation and drouth affords an unparalleled opportunity for the employment of the principle of succession, especially in the control and use of disturbance seres. The phytometer has been put to work on a vast scale by the California Forest Experiment Station in the analysis of the water cycle as embodied in the climate and climax of the chaparral in Southern California, and a similar comprehensive installation is being elaborated for the erosion program in grassland. The methods of ecological or natural landscaping have been developed in further detail, and are in process of being applied to the control and beautification of main highways and the enhancement of educational and esthetic values in national and state parks. Finally, the principles laid down in *Plant Indicators* (1920) for land classification, for optimum utilization, and for a contraction-expansion system based upon the climatic cycle are finding their first opportunity for social and economic service.

The outstanding climatic phenomena of the past two seasons have given occasion for the first endeavor to analyze erosion and flooding in terms of unit areas, in which the respective rôles of climate, cover, topography, disturbance and destruction can be given something approaching quantitative values. This has proven especially satisfactory in the case of wind erosion, where the anemometer has been employed to determine the force of the wind at various levels, the retarding effect of different communities and dominants at diverse heights and distances, and the depositional action of fences, tumble-weeds, roads, railways, buildings and other obstacles.

By way of providing an adequate background in the past and affording wide perspective in the present, the methods of paleo-ecology have been invoked to reconstruct the climaxes and climates of the more recent geological periods in those regions where the modern problems are most insistent. This has been done for the deserts and arid plains of the Southwest, and in collaboration with Dr. Chaney a similar endeavor is being carried out for the Great Plains and Great Basin. One of the novel features of the latter is the interpretation of the bad-land deposits of the Oligocene and the loess of the Pleistocene in the light of the present dynamic studies of eolian erosion and deposition.

CLIMATOLOGICAL RESEARCHES

By A. E. DOUGLASS

Climatological researches during the past year have extended chiefly in three directions; first, toward the fundamental facts of ring growth in the western yellow pine; second, upon tests of the accuracy and limitations of the cyclograph, the instrument upon which we depend for cycle analysis;

and third, toward strengthening the climatic values of the long Arizona chronology, announced a year ago in this report.

RING GROWTH AND LOCAL ENVIRONMENT

In tree ring studies, environment has to be considered in two separate classes between which it is most important to make a distinction; they are, local environment, which is essentially constant, and climatic environment, which changes from year to year. This difference is fundamental in isolating the climatic elements in ring growth. Cross-identification of rings between different trees follows from the climatic environment; general ring types follow the local environment. This difference has been the background of the writer's work since 1911 when the first observations were made upon it, but no formal advance had been made upon its details.

In the summer of 1934, Dr. Glock and the writer made many short trips about the northern Arizona pine forest to secure increment borings and other material illustrating the influence of local factors upon ring growth. The measurements of this material have not been completed, but the identification of rings while standing beside the tree reaffirmed the effects on ring growth of contours that help or prevent the accumulation of moisture in the soils. The differences of ring types at forest border and forest interior were confirmed. Shallowness of soil was recognized as of great importance. Some of the most sensitive ring records were found in exceedingly shallow sandstone soils where the bed rock cropped out and the roots of trees worked into the large cracks. Deeper soils accompanied more complacent rings. The cinder area northeast of Flagstaff showed often a large growth that was very complacent in the forest interior and became very sensitive on long, steep slopes near the forest border.

An important part of this review of local environment took us into the mountain ranges along the border between Arizona and New Mexico, north of the Santa Fe railroad. These mountains, south to north, are the Chuskas, Lukachukais and Carrizos. This area is sometimes called Central Pueblo Area (CPA) because here alone the ring chronology is carried back 1900 years. The advantages of a long chronology from one homogeneous source are obvious. During the past few years important specimens have been found here by Mr. Earl H. Morris, working in connection with the Carnegie Institution. Here the same general effects of environment were found to prevail as in the Flagstaff region, 160 miles to the west. Highly sensitive ring records were found at several places near Fort Defiance and complacent records secured higher up in the mountains.

UNIFORMITY OF RECORD WITHIN TREE

Another fundamental of our tree ring work in northern Arizona has been the recognition from the start of the practical uniformity of the record in different parts of the tree. This had come from two sources, the examination of the circuit of rings in transverse sections of probably a thousand trees, and a few incidental comparisons of the rings at different heights in the tree. Branches and roots had been examined rarely, so the test of a tree from top to bottom was needed.

In the Summer of 1934, Dr. Glock selected by increment borings several trees that, because of absent and double rings, would supply us with a wide range of facts. One of these, OL-12, on the cinder area northeast of Flagstaff, was cut down in October and sections taken each 5 or 6 feet in height beginning with section A, just above the roots, and ending on section J, about 6 feet below the highest foliage of the crown. Section B, about 5 feet above the ground, section F, amidst the heavy branches, and section I, near the top, each had 6 well-spaced radials measured. In the plots, the different radials are in most satisfactory agreement. The longest radius was measured in each of the 10 sections at different heights in the tree. These also appear almost exactly alike. The correlation coefficient of section A at the base, compared to the mean of the other 9, is 0.91 ± 0.01 between 1775 and 1934. Ring 1902 had the least growth of any in the tree, appearing in about 5 per cent of one section only, in section G, about two-thirds up in the tree. These and other rings, absent locally in limited degree, showed no distinct preference for any one part of the tree. The last ring formed, 1934, was essentially the same throughout the tree. The notable doubles were traced from top to bottom without discovering any pronounced preference for upper or lower sections.

The sapwood changed, however; it contained 140 rings at the bottom and only 100 at the top. Large branches and roots showed the same easily identified rings but the sequences were more erratic, with large trends, or "surges," here and there. The rings in the branches were apt to be much smaller than in the main stem. Both branches and roots showed eccentric centers.

The portions of the tree between the sections were then cut into slabs containing the growth axis of the tree. The examination of this is incomplete, but the $4\frac{1}{2}$ -foot log near the center of the tree, between sections D and E, was cut in a way that shows both longitudinal and transverse sections near the tree's central axis. In the longitudinal section, the inner rings retain their excellent spacing unless obviously distorted by branch growth, and the tip growth, easily identified as including the years 1694 to 1701, shows in a plotted curve very close agreement with corresponding ring-widths, both at the base of this log and at the base of the tree.

FUNDAMENTAL TESTS OF CYCLOGRAPHY

The rapidity and flexibility of the cyclograph was long known, and its accuracy had received some tests but had not been tried deliberately. The best general test of its work heretofore made was the "unknown scale" test, described in *Reports of Conferences on Cycles*, Carnegie Institution, 1929. In this test an analysis was first made of a large group of curves and results plotted in a periodogram; then the curves were all copied by an assistant at an unknown scale and the copies analyzed without knowing the identity of scale or curve. The values so obtained were then corrected by the assistant to true scale and plotted with the results of the first analysis.

Mr. Edmund Schulman became proficient in the use of this instrument and during the past year, in cooperation with the writer, has carried on a

series of tests of the cyclograph. One may recall that settings are made by the movement of a mirror on a track, which carries the scale of cycle lengths. On moving the mirror out and then in, the approach to the setting is reversed. He found in 216 cases an average difference in setting of 0.8 of one per cent of the cycle length. In comparing 30 or 40 curves analyzed by each of us at known and unknown scale, he found, on examining 200 or 300 cases, the average difference between known and unknown scale to be from 1.9 to 2.5 per cent of the cycle length. The difference between two observers in (a) 46 and (b) 95 curves was (a) 2.5 per cent and (b) 3.0 per cent. Inverted curves in some 400 cycle settings showed a mean difference of 2.4 per cent between the original and the inverted position.

He made a test of certain differences between the cycles in natural and random sequences. A group of 6 genuine tree growth curves and 27 lot drawing curves of about 175 terms in length was examined, the entire group being without any marks of identity; 5 of the 6 genuine were picked out as genuine by means of their cycles and the 6th was one of two called possibly genuine. Another contrast between natural and random sequences was brought out by taking some 30 or more random sequences, dividing them into two approximately equal groups, averaging the cycles in the groups, and taking the correlation coefficient between the two periodograms. One test gave 0.02 ± 0.12 , the other 0.05 ± 0.11 for resemblance between periodograms of random sequences. But 41 coast redwood curves of growth, divided into two groups and averaged as to cycles, gave a correlation coefficient of 0.56 ± 0.08 , one periodogram to the other.

Tests were made on synthetic curves, put together by Dr. Glock in 1932, whose component parts were unknown to Mr. Schulman. Seven such curves were tested. Out of 35 cycles in them, 30 were recognized on the first rapid analysis. Subsequent work added four more, and also weak cycles of little weight, distributed at random, evidently accidental in origin, which largely cancelled out when the results in which they occurred were summed into a periodogram. In this way attention is drawn to the long-recognized doubtful character of weak cycles.

LONG RING CHRONOLOGIES

The success of the past year in confirming the Arizona or Central Pueblo Area chronology back to A. D. 11 calls our attention again to its climatic value. Here we have an accurately dated sequence giving fairly close winter rainfall values for the last 1900 years. The opportunity of checking this against the still longer sequoia records is most important. Points of correspondence between Arizona and California in the early centuries of our era have already been noted. But more important yet, these two well-checked, parallel records give us the coveted opportunity of examining and noting the reappearances of familiar cycles during this long lapse of time. This cycle sequence and even cycle recurrence has already been noted in a number of cases. By means of these long sequences of rings, we obtain better approach to completeness in our survey of climatic cycles.

In the long Arizona chronology, as it stood a year ago, two weak points existed, one near A.D. 700, and the other in the series from A.D. 11 to A.D.

240. The identity of the rings near 700 has been amply confirmed by specimens from Allentown (Arizona) and Flagstaff, respectively, 95 and 160 miles from the first discovery point in the Lukachukai Mountains. The former were recovered by Mr. Carl F. Miller, working under Dr. F. H. H. Roberts of the Smithsonian Institution. The latter were handed me by Mr. John C. McGregor of the Museum of Northern Arizona, Dr. H. S. Colton, Director. These two contributions, each in the form of charcoal, have established beyond doubt the identifications of sequences near A.D. 700.

An improvement of great importance in the early part of chronology has come from the identification of M-143 collected by Mr. Earl H. Morris in 1927, at Mummy Cave. This is an excellent wood section with the bark on whose last growth ring identifies as A.D. 358. The center is at A.D. 93 and thus gives a greatly desired check on MLK 152, which had alone carried a good early series from A.D. 11 to about A.D. 239.

STAFF

Dr. Glock has worked on the relation of ring growth to rainfall and has prepared a manuscript on the use of tree rings as climatic indicators. This is to aid in the interpretation of fossil rings in geologic material. He has also assisted in much computation of statistical detail. Mr. Schulman has worked on the constants of the cyclograph in cycle study. Beginning in September 1934, Mr. Gordon C. Baldwin has worked on charcoal specimens and has measured extensive series of rings for the early Arizona chronologies. Later he did the dating and measuring of the rings in OL-12, which provided a long set of tests of uniformity of record in an Arizona pine.

COOPERATIVE WORK AND PUBLICATION

On February first a cooperative project was arranged with the University of Arizona leading to preparation of manuscript bringing a tree ring report up to date. In this arrangement, laboratory and work rooms are supplied on the University of Arizona campus. Dr. A. E. Douglass, while retaining status at the University of Arizona, is able to devote full time to tree ring work, especially along climatic lines. He is assisted as before by Dr. W. S. Glock. Mr. E. Schulman does the cycle analysis. Mr. G. C. Baldwin is doing the current ring work, identification and measurement of rings, preparation of specimens, and derivation of curves.

PALEOBOTANY

By RALPH W. CHANEY

Studies of Tertiary plants have continued along the lines described in previous reports and may be summarized as follows:

R. W. CHANEY—Emphasis has been placed on the later Cenozoic plants of China and the older Cenozoic plants of Western North America. The Pliocene vegetation of Asia has been little known, as is also the case in North America. Floras of this age have been studied from Shansi, Tibet, Kansu and Sinkiang, and indicate a semiarid climate in Northern China during this epoch. The occurrence of fossil pond-lilies and other aquatic plants offers

a possible source of food for the shovel-tusked mastodons (*Amebelodontinae*) which occur in rocks of this general age on both sides of the Pacific, and whose extinction appears to have been due to the drying up of many of the lakes in the interior of China and Western North America.

Plant remains associated with the bones and cultural record of *Sinanthropus* (Peking Man) definitely suggests a cool, dry climate in Northern China during the Pleistocene epoch. Such an environment is consistent with other evidence recently accumulating regarding the associated faunas.

The older Tertiary floras of Western America show a sharply contrasting picture. Warm, humid climate is indicated by the fossil plants from the Clarno of eastern Oregon, the Steel's Crossing flora from west of the Cascades in Washington, and related floras in California. There is a marked uniformity in the Eocene vegetation of Western America, which is being studied in comparison with the modern forests of Mexico and Central America.

Marked restriction in forest distribution, resulting from climatic and topographic changes during later geologic time, is apparent in the modern occurrence of the coast redwood and of other conifers on the Pacific coast. The educational program of the Save-the-Redwoods League and of the California State Parks Commission has included the writing of pamphlets and the supervision of nature guides in the State Parks where these trees have survived.

Investigations of several associates and students have been supervised, and seven papers written by them have been published.

M. K. ELIAS—Critical collections of late Tertiary age from the High Plains show definite relationship to floras of corresponding age in the Great Basin. These collections are being studied with R. W. Chaney.

E. I. SANBORN—A report on the Comstock flora has been completed. Definitely dated by associated marine invertebrates, this flora shows a marked relation to older Tertiary vegetation elsewhere in Oregon and in California and Washington. A Miocene flora from west-central Oregon is now being studied and is of particular interest because it is one of the few well-represented assemblages of this age west of the Cascades.

R. S. LAMOTTE—The Upper Miocene flora from 49 Camp, Nevada, and vicinity has been studied, and preliminary papers involving climatic and taxonomic considerations have been published. The discussion of an Oligocene florule from British Columbia has also been brought to print.

S. P. GILMORE—An investigation of older Tertiary plants from Plumas County, California, has been completed and is being printed. This flora includes many species recorded from the Eocene in other parts of Western America and has modern equivalents in the forests of low latitudes in both hemispheres.

H. D. MACGINNIE—Additional collections have been made at Chalk Bluffs and elsewhere in the auriferous gravels, and a report is being prepared. A study of two older Tertiary floras from Trinity County, California, is nearing completion.

L. H. DAUGHERTY—Further collections from the Triassic of the Southwest indicate that there was a wide-spread and diversified type of vegetation in this region during the early part of the Mesozoic era. Various Cenozoic

woods have been sectioned and identified, resulting in the corroboration of determinations based on leaf fossils. The woods associated with remains of early man in Texas indicate a dry climate similar to that in which *Sinanthropus* made his home during the same epoch in Asia.

II. L. MASON—A report on the Tomales flora from the Pleistocene of west-central California has been published, and other studies of floras of this age are in progress.

C. CONDIT—Collections have been made and a report is in preparation on the San Pablo flora of Miocene age from west-central California.

D. I. AXELROD—A preliminary paper has been published on a Pliocene flora from southern California.

DEPARTMENT OF TERRESTRIAL MAGNETISM ¹

JOHN A. FLEMING, DIRECTOR
O. H. GISH, ASSISTANT DIRECTOR

INTRODUCTION

During the report-year, July 1, 1934, to June 30, 1935, the activities of the Department have followed in general the lines indicated in last year's report. These are: (1) Reduction and study of accumulated observational data; (2) further development of technique and apparatus to record photographically the electrical conditions and variations in the ionosphere, and their investigation and correlation with other geophysical phenomena; (3) continued theoretical formulation and experimental investigation, in the laboratory, of basic aspects of nuclear physics and magnetism; (4) maintenance of observational program in the field to make for continuity of secular-variation data and of recording at observatories of the Department the seasonal, diurnal and irregular changes in the Earth's magnetic and electric fields.

As in past years, every opportunity has been taken to encourage and to cooperate with organizations everywhere engaged in geophysical research similar to that of the Department. This is in accord with the growing efforts toward world-wide coordination sponsored by various international scientific bodies and congresses. Such coordination with studied and planned unification of methods and aims in attack is peculiarly necessary for advance in terrestrial magnetism and electricity.

An outstanding event for geophysical science was the decision in March 1935 of the British Admiralty to construct a non-magnetic vessel—to be named *Research*—to continue the magnetic survey at sea of the *Carnegie*. Upon request of the Admiralty, plans and specifications of the *Carnegie* and designs of instruments, as evolved during the many years of the Department's oceanic work, were supplied. Arrangements were completed that William J. Peters, who was for many years in command of the *Carnegie*, go in the fall of 1935 to England as a consultant on the design and construction of the new vessel and of her instrumental equipment.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM

ACTIVITY AND VARIATIONS OF EARTH'S MAGNETIC FIELD

Analysis fluctuations—The experimental evidence available in many branches of geophysics and cosmical physics differs from the readings taken in laboratory research in so far as, in the laboratory, the observations are taken under fixed conditions or involve only a limited number of variable quantities, while the records obtained at geophysical laboratories show variations in time which are not easily expressed as the effect of a few variables. The analysis of such time-functions, and of the interrelations existing between them, is, therefore, an indispensable part of geophysical research. This holds in particular for the more or less pronounced fluctua-

¹ Address: 5241 Broad Branch Road Northwest, Washington, D. C.

tions variously termed cycles, periodicities, or recurrences, and shown to exist in various phenomena not only in geophysical and cosmical physics, but also in geology and biology.

Every attempt to find cycles has to consider the mathematical fact that any time-function $f(t)$ which is given, in a finite interval of time, by a finite number of values—for instance, hourly or daily values—can be represented as the superposition of a finite series of cyclic functions, such as sine-waves, and for one and the same given function $f(g)$ an unlimited number of such series can be found. If, therefore, a representation of $f(t)$ by means of a series of superposed cyclic functions has been effected, this does not at all entitle one to regard the individual cycles as physically significant constituents of $f(t)$. This fact has, in some form or other, often been overlooked in research on cycles because the attention has sometimes been centered on a mechanization of the labor necessary for working out such representations; many cycles have, in this way, become the subject of serious discussion as to a possible physical meaning. To prove the physical significance of any cycle, it is in most cases sufficient to demonstrate that it recurs frequently enough, and this consideration of frequency leads, in some way or other, to statistical methods and to the theory of probability.

In a paper on "Random fluctuations, persistence, and quasi-persistence in geophysical and cosmical periodicities" (Terr. Mag., vol. 40, 1-60, 1935), this fundamental statistical aspect has been considered by Bartels. Research on periodicities is transformed into the discussion of the geometrical properties of clouds of points or of sets of vectors in harmonic dialys of two or more dimensions, and this geometrical illustration, for which simple formulæ are readily available in pure mathematics, allows a clear insight into practically all pertinent questions. Between the two extreme cases of random fluctuations and persistent waves, hitherto discussed exclusively, the intermediate case of quasi-persistence, in various forms, is introduced and recognized as a common phenomenon in time-functions of geophysics, etc. Extensive examples are worked out, mainly dealing with terrestrial-magnetic activity which exhibits several types of periodicities. The general conceptions of the random walk, the equivalent length of sequences, the effective expectancy, and the infective property of quasi-persistence on adjacent periods are abstracted from these examples. It is also demonstrated how quasi-persistence affects the tests for significance of persistent periods as established by former periodogram-methods; in this way, several cycles are wiped out which owed their apparent physical reality only to more or less concealed misconceptions. No restriction to sine-waves is necessary, any form of cyclic functions, even of changing phase or period, being admitted. The methods developed are flexible enough to allow a wide-range of applications as described in the published paper.

Solar activity—A day-by-day record of terrestrial magnetism and solar activity in the form of a diagram demonstrating the 27-day recurrences in the 11-year cycle 1923 to 1933 was prepared by Bartels (Terr. Mag., vol. 39, 201-202, 1934). The exceptional length of the sequences at the end of the 11-year cycle (from about 1929) is striking, as compared with the rather spotty appearance at the beginning. The purpose of the solar diagram is to invite comparison with the magnetic diagram and reexamination of the

results obtained formerly. The last years 1930 to 1933 illustrate again the fact that strong and long-lived magnetically active *M*-regions (see Year Book No. 31, 259-260) on the Sun persist through long times in which the Sun appears practically spotless, or, in other words, that small or zero sunspot-numbers comprise many different degrees of solar activity with respect to its geophysical influences.

Secular change in the magnetic solar diurnal-variations—A complete change in the character of the solar diurnal-variations in vertical intensity has been observed at the Huancayo Magnetic Observatory during the past sunspot-cycle. Characteristics of the southern type of variation, present during the northern-summer solstice in 1922, gave place in 1932 to a form of variation characteristic of the Northern Hemisphere. This change is associated with the secular change of the Earth's general magnetic field which consisted partly of a southern shift of the magnetic equator in the region around Huancayo. Detailed features of this change are found by McNish to be qualitatively in agreement with the expected changes resulting from such a movement of the magnetic equator. The large magnitude of the changes indicates, however, that the solar diurnal-variation is a complex function of the Earth's general field, such as is called for by the atmospheric-dynamo theory of Balfour Stewart. Statistical considerations lead to the conclusion that the change is established to an extraordinarily high degree of probability.

Magnetic diurnal-variations in the Western Hemisphere—Good progress was made by McNish on the potential analysis of the magnetic diurnal-variations in the Western Hemisphere using the data from the Huancayo Magnetic Observatory and from the Agincourt, Cheltenham, Vieques, and Pilar observatories for the five international quiet days of the equinoctial months of 1923. Essentially Schuster's method of analysis was used, taking geomagnetic instead of geographic coordinates. This new analysis seems needed because the coefficients derived by Chapman through analysis of records from world-wide distribution of observatories fail to adequately describe the variations in the Western Hemisphere. The new coefficients fit the data from the five observatories much better than Chapman's, particularly in the case of the northward component of the variations.

A current-system deduced, which would give rise to the magnetic variations in the region considered, shows a considerable crowding of the lines of flow over the region of Huancayo with preponderance of eastward current between the magnetic and geographic equators shortly before midday. The current-vortex in the Northern Hemisphere is about equal in magnitude with that deduced from Chapman's coefficients, but its focus was displaced some 10° southward, while the current-vortex in the Southern Hemisphere is over twice this magnitude.

The internal and external portions of the variation-field are in approximately the same ratio as found by other investigators except for the higher-degree harmonics in which the internal field is disproportionately large. In these harmonics the internal portion lags behind the external portion in phase instead of leading it as is the case for the lower-degree harmonics. These effects might be expected if the higher-degree harmonics are of greater

importance in the external system as it exists shortly before culminating over the 75° west meridian near which all of the observatories used are situated.

To throw further light on this anomalous current-system electromotive forces at various portions of the Earth were computed using the observed values of the vertical magnetic field and the air-velocities which satisfy the equations of the solar-semidiurnal atmospheric tide. These electromotive forces show that, in general, the current must flow against the electromotive forces in equatorial regions in order to close. In the region over South America where the magnetic equator is displaced considerably south of the geographic equator, there are appreciable electromotive forces favorably directed so that the current-flow may close more readily. This is believed to be the cause of the denser current throughout this region.

Attempts to reconcile the diamagnetic theory and the drift-current theory with the results of the potential analysis are now in progress. It does not appear at present that the attempts will be successful, the conclusion being that the atmospheric-dynamo theory of Balfour Stewart is still the most plausible explanation of the solar-diurnal magnetic variations which has been proposed.

The diurnal variation of earth-current potentials at Tucson computed from the coefficients of the internal portion of magnetic-variation potential are in rough formal agreement with the variations observed at that station by the Department in cooperation with the United States Coast and Geodetic Survey, although the magnetic results from Tucson were not used in making the potential analysis.

Lunar diurnal-variations of the Earth's magnetism---Miss Assmann, with the cooperation and supervision of Schneider, worked on the lunar magnetic variations at Huancayo, declination 1922-32, and horizontal intensity 1927-32. For tests on quasi-persistence, in comparison with Huancayo results, declination observations at Batavia (1906 to 1929, December solstice) were worked up in a similar way. Schneider prepared a paper on "Einflüsse der Sonne auf die lunaren Variationen des Erdmagnetismus," based on declination observations made at Huancayo, 1922 to 1932, and Batavia, 1906 to 1929. This demonstrated an increase of lunar diurnal-variations with solar activity. Furthermore, a considerable degree of quasi-persistence was traced; from the average diurnal magnetic variations which are normal for the season, terrestrial-magnetic and solar activity, the individual diurnal-variations on consecutive days deviate mostly in the same way. This quasi-persistence, already indicated in papers by S. Chapman and J. M. Stagg, is shown to be effective in solar and lunar diurnal-variations alike, thus impairing the statistical reliability of average diurnal-variations just as if the number of observations were cut to less than half. An unexpected explanation is thus offered for the rather erratic aspect often found in average diurnal-variations obtained for groups of days, presumably large enough in number, selected according to solar activity, lunar distance, etc.

In view of the large amplitudes of the solar diurnal-variations (S) in horizontal magnetic intensity at the Huancayo Magnetic Observatory, a study of the lunar diurnal-variations (L) in horizontal intensity also seemed rather

promising. The results of the discussion by Schneider and Bartels for the six years 1927-32 have fulfilled these expectations to a surprising degree. In southern summer (means of the months November to February), on the average for all days with international character-figure not higher than 1.1, the main term, the 12-hourly lunar wave (L_2), has a harmonic amplitude of 9γ ($1\gamma = 0.00001$ c.g.s. unit), which is more than one-third of the solar 12-hourly wave (S_2), namely, 25γ . Thus the combined solar and lunar 12-hourly waves vary in amplitude from $3\frac{1}{2}\gamma$ when they are in phase to 16γ when they have opposite phases.

This lunar wave is not only in absolute size, but also in relative magnitude compared with the solar wave, the largest so far found for any observatory. It lends itself, therefore, well for studies of the change of L_2 with magnetic activity, sunspot-numbers, etc. For a station so near the equator, the radically different seasonal changes of S and L are significant. While S remains about the same throughout the year, L decreases in the ratio 10:1 from December to June! This fact is a new argument for Chapman's assumption that S and L originate in different layers of the ionosphere and will prove of value when the direct ionospheric research by wireless methods, now in progress at the Huancayo and Watheroo magnetic observatories, is combined with the magnetic results.

Magnetic and auroral activity—Data from Little America (magnetic latitude 74° south) for 1929-30, Point Barrow (magnetic latitude 69° north) for 1932-33, and Chesterfield (magnetic latitude 74° north) for 1932-33 were discussed by Davies. For any one station, greatest magnetic and auroral activity were found to occur at approximately the same time during the night. At all three stations greatest auroral disturbance appeared to occur near magnetic latitude 70° . Greatest magnetic disturbance has been shown to occur also near this latitude. Diurnal variation in magnetic activity was found to be of a double-maximum type with great seasonal variation for Chesterfield; but for Little America, at the same magnetic latitude, it was of a single-night-maximum type. Data from Point Barrow showed a single maximum at night. The data at both Point Barrow and Chesterfield conform in this respect with the results of Stagg's investigation, but Little America data shows the "outer"-zone instead of "transition"-zone type. The boundary between these zones is approximately 70° magnetic latitude. The time of the night maximum in diurnal magnetic-activity at these stations appears to be more closely related to geographic than to magnetic latitude.

Ennis subjected auroral and magnetic observations at Little America during June, July and August 1929, to statistical analysis and determined correlation-coefficients. From a comparison of about 1500 pairs of magnetic declination and auroral intensity the following conclusions were reached: (1) The greatest activity in each phenomenon, on the basis of hourly ranges, occurs about 9^h to about 19^h ; (2) the times of maximum and the times of minimum values of the two elements are in good agreement; (3) on the basis of averages, the declination values for times when auroræ were present are greater than those when no auroræ were observed; (4) a more or less loose, in some cases fairly high, correlation is shown.

INSTRUMENTAL INVESTIGATIONS

Improved design of vertical-intensity variometer—There is no doubt that the magnetic records from all observatories suffer from the inherent mechanical deficiencies of the "balance" type of vertical-intensity variometer. These are evidenced in greater part by the failure of the knife-edges and pivot-points which support the magnet-assembly to produce truly frictionless motion as they rock on the supporting surfaces, whether these be plane, cup-shaped, or cylindrical. Even with a reasonable and a needed sensitivity of approximately 3 to 4 gammas per mm., unaccountable shifts in the base-lines of this type of instrument with accompanying changes in scale-value occur at irregular intervals. Such chance occurrences emphasize the need for a vertical-intensity variometer which will avoid the use of magnet-support by pivot or knife-edge. The Watson variometer was a step in the right direction in that the magnet-assembly was supported by a quartz-fiber suspension; its unhandiness, however, and the difficulty of renewing suspensions make it an unattractive instrument for observatory use. Following the recent rapid developments of special alloys of steel, McNish utilized an old idea in a vertical-intensity variometer, employing elements of specially heat-treated invar steel. The variometer consists of four vertical staves of the special alloy called "perminvar," two staves mounted above and two below so that the flux induced by the Earth's vertical field passes through the staves. An air-gap is left between the upper and lower staves in which an armature of perminvar is suspended by a vertical quartz-fiber. Torsion in the fiber tends to move the armature out of the air-gap, from which movement it is restrained by the flux induced in the material by the Earth's vertical field. Slight changes in the vertical field cause the armature to move in or out of the gap, the movement being recorded in the conventional way. The special properties of perminvar which permit this use are: (1) Constant permeability up to three gauss; (2) no measurable hysteresis-loss up to three gauss. Thus the armature returns to identical positions for identical values of the Earth's vertical field. This type of variometer is expected to give more consistent performance over long periods of time, owing to the fact that the moving parts are suspended by quartz and do not rest on knife-edges or pivot-points. The Department has had an experimental instrument in operation at a sensitivity of slightly less than 4 γ per mm. for some time at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey.

Improved methods of using sine-galvanometer—Preparatory to installation as standard in horizontal intensity of C.I.W. sine-galvanometer No. 1 at the Cheltenham Magnetic Observatory, Forbush and Johnson improved the methods and equipment for the measurement of current in it so that its accuracy now approaches more closely the limits set by the uncertainty in the coil-constant. The shielded wires of the sine-galvanometer were renewed, bakelite clamping-blocks provided, as also a new block for holding the wires with an improved ground-clamp. The standard cells, standard resistance, and air-cells which supply the current for the coils and potentiometer were mounted in a well-insulated, metal-shielded thermostatically controlled cabinet. The potentiometer, galvanometer and control-panels are mounted

on top of the cabinet and all necessary operations for the determination of horizontal intensity can be carried out by a single observer.

Development of electromagnetic instruments—From October 1934 experimental work has been done, in cooperation with the United States Coast and Geodetic Survey through its Division of Terrestrial Magnetism and Seismology at Washington and at the Cheltenham Magnetic Observatory, on the development of a new type of absolute standard to measure all elements of the Earth's magnetic field. The design is for the use of a pair of Helmholtz coils wound on a special coil-form of pyrex glass with a modification of a rotating coil as a detector using an alternating-current amplifier to detect the small voltages. It will be possible to measure any desired component of intensity, declination and inclination to one part in 25,000. Experimental models of the detector have shown the method to be feasible.

The auxiliary apparatus to measure small alternating-current voltages has been built after Johnson's design. This consists of a high-gain alternating-current amplifier capable of measuring voltage from 10^{-9} to 10^{-1} volt over the range from one cycle per second to 50,000 cycles per second, a dynatron-oscillator with automatic control of amplitude with a frequency-stability of one part in 100,000, a dynatron-tuned circuit, an accurate voltage-divider, an alternating-current bridge for measuring a wide range of inductances and capacities with an associated amplifier, several power-supplies, and appropriate meters of special design.

TERRESTRIAL ELECTRICITY

The development of instruments and of experimental and investigational work in terrestrial electricity was done by Gish, Rooney, Sherman and Wait. As temporary assistant computer, Prescott assisted in phases of this work.

ATMOSPHERIC ELECTRICITY

Studies of data from College-Fairbanks Polar-Year Station—Gish and Sherman, assisted by Prescott, made a large number of independent determinations of the ratio between the potential gradient at the standardizing station to the potential at the variation observatory because of the considerable amount of satisfactory registrations obtained simultaneously at the two stations. These ratios or reduction-factors varied somewhat from month to month but not in such a way as to denote an annual variation, the largest and most abrupt change being from a minimum (1.03) about January 1 to a maximum (1.17) about March 1. It has not been possible to find a correlation between these and meteorological changes. The mean of all determinations is 1.09.

The reduced values of potential gradient show a distinct annual variation, a sharp maximum occurring in January and a flat minimum coming between May and October. The annual variations in both positive and negative conductivities are opposite to that in potential gradient. A study of the values of the ratios of positive to negative conductivity showed a marked direct proportionality between these and potential gradient. However, other factors obviously come into play to disturb the simple relationship. Thus the factor of proportionality undergoes an annual variation nearly like that

of the potential gradient. Although a study of meteorological factors gives some indication that the annual changes in this relationship may be attributable to a combined effect of wind-velocity and the height of the lower inversion-layer, yet the available meteorological data seem to be inadequate to settle this question.

The average values are as follows for all days: Potential gradient, 104 v/m; magnetic conductivity, 1.74×10^{-4} e.s.u.; negative conductivity, 1.41×10^{-4} e.s.u. For ten selected days the average values are as follows: Potential gradient, 97 v/m; positive conductivity, 1.90×10^{-4} e.s.u.; negative conductivity, 1.41×10^{-4} e.s.u. The mean value of the ratio of positive to negative conductivity is 1.55. The extremes in monthly means are 2.09 (February) and 1.26 (June). Convincing evidence that the values of this ratio are not appreciably influenced by the type of exposure used at College was found.

The result of an harmonic analysis of the diurnal variation in potential gradient, using 10 selected days each month (except only six in June), in all of which the maximum variation from the mean of the day was less than 100 per cent, gave the following for the year: $G = 97 + 14 \sin(\theta + 183) + 7 \sin(2\theta + 225) + 2 \sin(3\theta + 228) + 2 \sin(4\theta + 348)$, where G indicates potential gradient in volts per meter and θ is counted as 15° per hour from Greenwich midnight.

Factors controlling the conductivity of the lower atmosphere—One of the principal factors controlling the conductivity of the lower atmosphere is the small-ion content. The small-ion content depends upon (a) the rate of production and (b) the rate of destruction of the small ions. The ion-content of the atmosphere at Washington, together with the causes for its variations, is being studied by Wait. The rate of production of small ions is being obtained by means of a thin-wall ionization-chamber, and the rate of destruction through an investigation into known destroying agencies. The combination-coefficient between small and large ions has been computed from simultaneous data on the small-ion production in the atmosphere. The computed values vary as the reciprocal of the large-ion content of the air, the lowest value being 4.3×10^{-6} and the highest value being 6.4×10^{-6} for large-ion contents of 2440 and 1460 ions per cc., respectively. Such variation in the combination-coefficient is difficult to reconcile with known physical processes. An alternative interpretation is that the coefficient remains constant at 1.0×10^{-6} , but that the small ions are destroyed through other processes at a rate proportional to the number of small ions present.

The intermediate ion of the atmosphere—Investigations by Wait during the year have added materially to the available information regarding the intermediate ion of the atmosphere. Contrary to the findings of Pollock, the results indicate that these ions do not diminish at any vapor-pressure below saturation owing to the formation of large ions through condensation of water-vapor. Their mobility was found to vary with the vapor-pressure of the atmosphere in accordance with Blanc's law. Their number varies through the day in a manner similar to the large-ion number and more or less opposite to the small-ion number. The recombination-coefficient for ions of this class was found to be 7.1×10^{-7} . The intermediate ions are especially numer-

ous during times of thunderstorms as first observed by Schachl, not as a consequence of the Lenard effect as inferred by him, but because of the increase in the small-ion content of the atmosphere during such times. The mobility-spectrum for the intermediate ion appears to be a narrow band. Under normal conditions practically no ions having mobilities between that of the intermediate ion and that of the large ion were found. Errors ranging from 10 to 30 per cent in small-ion counts will result if the intermediate ions collected by the small-ion counter are not taken into account.

Distinction between Langevin ions and dust-particles in the atmosphere—The analysis of large-ion data taken simultaneously with Owens dust-count data by the United States Weather Bureau generally shows a positive correlation between the two elements. During times of high dust-count due to dust-storms in the west, the large-ion content failed to show a corresponding increase. These results were taken to mean that the Owens dust-particles are in general composed of smoke particles, the number of actual dust-particles being more or less negligible. The large-ion content of the air also is affected by the amount of smoke in the air. The dust-particles, while increasing the count with the Owens instrument, for some reason—possibly their large size—do not contribute appreciably to the large-ion content.

Variation of small-ion production near the Earth's surface—Measurements by Wait and McNish of small-ion production in a thin-walled vessel at Washington demonstrates the existence of a regular diurnal-variation in the production-rate similar in form to the inverse of the daily temperature-curve. The decreased rate of production toward the middle of the day is interpreted as due to a diminution of the radium-emanation content in the lower region of the atmosphere through scattering by turbulence. Contrary to general beliefs, there is found here no apparent connection between the rate of small-ion production and changes in the barometric pressure. Other variations in the rate of production of small ions, apart from that occurring during thunderstorms, take place and do not seem to be associated with any meteorological phenomenon. Tests together with calculations indicate that this ionization-chamber is about 50 per cent effective for measuring the effect of alpha particles. The average ionization in the free atmosphere on the grounds of the Department approximates eight to twelve ion-pairs per cc. per sec. A chamber with a thick wall showed no increase in ionization during thunderstorms, which indicates that the increase at such times is due to the effect of alpha particles, in conformity with the hypothesis previously advanced as to the cause for the increase in ionization during thunderstorms.

Improvements and flight-tests of apparatus for registering air-conductivity in the stratosphere—The apparatus constructed by Gish and Sherman, assisted by C. Huff and Steiner, during the last report-year (see Year Book No. 33, 210) primarily for use in the National Geographic Society-Army Air Corps stratosphere flights was further improved by adding a device by means of which the sensitivity could be altered simply by turning a double-pole selector-switch to any one of five selected values which, by suitable connection with batteries, may be made to vary many fold. Other minor improvements were also effected. A ready means of selecting a range of sensitivities is desirable in an apparatus where the quantity to be measured

varies over such a range as is to be expected for air-conductivity in ascending from the Earth's surface to an altitude of 20 km. (12 miles) or more. Another improvement is a switch and connections for changing the registration from that of positive to that of negative conductivity. In the earlier form of the apparatus it was planned to register only positive conductivity and, on account of the lack of ready means of changing sensitivity, to make a sacrifice as to the details of the lower atmosphere in order to register with a suitable sensitivity at the higher altitudes. The improved apparatus is designed to eliminate these limitations and to obtain data richer in quality and detail. After thorough testing in the laboratory, including cold-chamber tests at the National Bureau of Standards, the apparatus was taken to Wright Field where it was fitted into the gondola of *Explorer II* and subjected to further tests. Then, in accordance with arrangements made by the Advisory Committee of the National Geographic Society-Army Air Corps stratosphere flights, the apparatus was taken by airplane (in which it was so mounted as to operate en route) to Scott Field, where two successful flights were made by Captains Anderson and Williams on April 21 and 28 in an 80,000-cubic foot, open-basket balloon, reaching altitudes of about 27,000 and 26,000 feet, respectively. The apparatus functioned satisfactorily in both flights. The registrations showed a somewhat irregular increase of conductivity, both positive and negative, as the balloon ascended, the values at the top being in both flights about 20 times the surface values. Similar trends were shown on the descents.

Registration of air-potential and air-conductivity at "Strato-Camp," South Dakota—In order to amplify the measurements of air-conductivity to be made with apparatus affixed to the gondola of the balloon *Explorer II*, it seemed desirable to obtain measurements of air-conductivity and potential gradient at a ground-station where the electrical state of the air, especially the air-earth current, is likely to be representative of the region over which the flight would take place. Such measurements made during the flight would yield a value for the air-earth current, which, when divided by the conductivity registered from the balloon, should give a value of the potential gradient at the higher altitude. This of course assumes that the air-earth current-density is constant with altitude, a condition which it seems must be closely approached over an area where there prevails stable, fair weather, such as is likely to be chosen for a stratosphere flight. Such data as it was proposed to obtain at the ground-station while waiting for weather suitable for inflating the balloon seemed valuable, quite apart from the high-altitude measurements, since information of that character has thus far been obtained at so few places.

An apparently suitable place for a ground-station was found near the rim of the "Strato-bowl." The apparatus set up by Gish and Sherman in a simple hut was in operation at that place 34 days at the end of the report-year, 32 complete days of air-potential and 30 of conductivity being obtained. Sixteen of these were free from negative potentials. The diurnal variation in air-potential found at that station closely resembles the type observed at sea.

Tests and calibrations of air-flow meters—Tests of four Rosenmüller air-flow meters used in the Department were made by Sherman with simple equip-

ment, which by facilitating such tests will encourage more frequent check-ups in the future. The tests showed that the operation of the newer type Rosenmüller meters, which are provided with a port that restricts the air-stream to the most favorable part of the vanes, is within a wide range of conditions relatively insensitive to the type of connection to and from the meter. The tests and these calibrations, taken in conjunction with others previously made at the National Bureau of Standards, also demonstrated that meters of this type when in frequent but intermittent use maintain their calibration over several years at least without cleaning. Meters which have been in continuous use collect dirt which appreciably alters their calibration in six months or a year of service under air-conditions which prevail at this location. However, the meters which showed such an effect were restored by bathing the train of gears in ether.

Preparation of quartz-fiber elements—The preparation of quartz-fiber elements by Sherman for Lauritsen-type electrometers involved some difficulties at the outset, which were traced to the very appreciable weight of platinum, which is deposited in our usual practise of electrical sputtering. Heretofore fibers which were to be used in making elements for other electrometers have been sputtered 10 to 15 minutes. The coating thus obtained is, however, far too heavy if the fibers are to be used in Lauritsen electrometers. Fibers sputtered for five minutes, although serviceable, are distinctly heavier than those used by Lauritsen, the dimensions having been taken into account. It now seems that in two or three minutes the coating of platinum laid down in the Department's sputtering chamber will be comparable to that used by Lauritsen.

EARTH-CURRENTS

Reduction of records—The earth-current records have been kept current by Rooney in reduction and tabulation of the data received from the Watheroo, Huancayo, and Tucson observatories. In the case of Watheroo and Huancayo records, only such preliminary studies have been made as suffice to check on the performance of the measuring systems and the consistency of the duplicate independent records. The continuity of recording at all three observatories has been maintained without serious loss of record and no alterations or extensive repairs have been found necessary.

The series of earth-current records (practically unbroken) now extend for Watheroo over eleven calendar years (to end of 1934) for the north component and eight years for the east component (the first three years of east-component records at this station not being counted because they contain an appreciable spurious diurnal-variation component). For Huancayo the series extends over eight years for both components, the first three years being not as complete as desirable for our purposes. For Tucson the series covers three years.

The question as to how long it is desirable or justifiable, all circumstances considered, to carry on such continuous registration was of course given thought at the outset. The selection of material for the installation, the design of equipment, and other plans naturally hinged somewhat upon that decision. The tentative decision then reached was that plans should be based on a duration of two sunspot-cycles. The data at Ebro gave strong indication of

a correlation between aspects of earth-currents and sunspottedness, and hence it seemed likely that data extending over two cycles at several other observatories would be adequate to definitely determine the extent to which we may generalize regarding this matter and perhaps they would also yield results adequate for such quantitative studies as might be required.

Studies by Gish and Rooney of the data from these three observatories show that the solar diurnal-variation and its variation during the year, as well as most features of shorter-period variations and their relationship with corresponding variations in terrestrial magnetism and polar lights, may apparently be determined from a series of registration of only a few years' length.

However, in order to obtain a satisfactory evaluation of the lunar diurnal-variation and of a variation of period corresponding to that of sunspot-numbers, longer series will be required. An examination of the data accumulated to date reveal for both Watheroo and Huancayo a high correlation between diurnal range in earth-currents and in sunspot-numbers. Although the percentage variation in range R for both stations approximately satisfies the relation $R = (0.6S + 80)$, where S is the sunspot-number, yet the departures, apparently all random, are such that the series should extend over at least two sunspot-cycles in order that the derived data may have the required significance in the quantitative studies which will eventually be required to check any theory advanced in explanation of these and associated phenomena.

Seasonal variation in earth-currents at Tucson—Final reduction of the Tucson records for the three-year period 1932-34 has been completed by Rooney and a condensed summary of the results including diurnal-variation data by months for all days recorded and for ten calm days per month prepared for publication (see Terr. Mag., vol. 40, 183-192, 1935). Chief interest in these results lies in the seasonal variation in earth-current flow at this station, which is situated in the "zone of transition" where the diurnal variations of magnetic dip and intensity change from high-latitude to equatorial type. The preliminary findings with respect to seasonal changes as summarized in the Annual Report of 1933-34 (see Year Book 33, 211-212) have been confirmed by the final records based on the three calendar years reported. These seasonal changes are most readily appreciated when the diurnal-variation data are given in hodographs, the form of which varies markedly from month to month but repeats itself closely in the same months of different years. The winter hodographs are nearly circular with the current-vector proceeding in two clockwise loops, that traversed during the daylight hours being much the larger. During the summer, the hodographs are elongated greatly along a line which corresponds closely to the magnetic meridian and the clockwise rotation of the vector tends to disappear at midday. The graphs for the equinoctial months are intermediate in form, resembling in most cases the hodograph constructed from mean-annual-diurnal-variation data. A regular progression of the seasonal change is found throughout the year, except in the months of January and March, the records for which are anomalous, each in a different aspect. In January the amplitudes of both the northward and eastward components are considerably

greater than those recorded during the other winter months, while the phasc-relationship maintains its regular winter character. During March, on the other hand, the northward component follows its normal trend toward increasing amplitude with increasing height of Sun, but the eastward component becomes so small and irregular that the hodograph reduces almost to a jagged line.

The changes observed in the flow of the earth-currents can not well be associated with variations in the conductivity of the region or with structural irregularities. Hence it appears that they must be associated with variations in the inducing phenomenon. This conclusion is strengthened by comparison with the diurnal-variation curves of the magnetic elements. Comparing the northward earth-current curve with the first derivative of the curve for Y , the eastward component of the horizontal magnetic field, and examining the eastward earth-current curve in conjunction with that for X , the northward magnetic force, there is found a decided parallelism in the manner in which the two pairs of curves change from month to month. This parallelism extends even to the anomalies noted in the January and March records. This would appear to be an important addition to the evidence linking the two phenomena together, and a day-by-day comparison of the two sets of records suggests itself as a promising study to throw more light on the true relationship between them.

Earth-currents in polar regions—Reduction and analysis of the earth-current data collected at the College-Fairbanks (Alaska) Polar-Year Station for the one-year period October 1932 to September 1933 were completed by Rooney and Sherman. A general summary of the results at this station will be found in the Annual Report for 1933-34 (see Year Book 33, 212-213) and detailed diurnal-variation data by months in the Journal of Terrestrial Magnetism and Atmospheric Electricity (vol. 39, 187-199, 1934). Registration of earth-current potentials at the College-Fairbanks Station was continued through a second winter, until the end of March 1934, by E. R. Johnson of the United States Coast and Geodetic Survey. Scaling, reduction, and compilation of the records for this six-months' period were completed by Rooney and the results confirm the records of the previous winter. Compilations of the hourly ranges in earth-current potentials for selected winter and summer months were also prepared and made available for correlation studies with aurora, magnetic activity and other phenomena.

An examination by Davies of earth-potential records at Chesterfield and College-Fairbanks in the "transition" and "outer" zones, respectively, showed that diurnal variation of hourly range in potential was very similar to the diurnal magnetic-activity variation typical of these zones.

Earth-resistivity—Interest in the method and equipment developed in the Department for measuring the resistivity of undisturbed earth continued to be manifested. A number of requests were received for advice regarding instrumental features and technique. Some of the problems in which this method was considered as a possible aid were: Surveys of ground-water; study of the intrusion of salt water into fresh-water wells; location and survey of gravel-beds; surveys for gaining knowledge of geological structure required in engineering projects such as road-building and dam-construction.

INVESTIGATIONS OF THE IONOSPHERE

Research in the ionosphere—The importance of modern developments in the technique of wave-propagation for studies of phenomena definitely related to those of terrestrial magnetism and electricity and of others such as radio wave-propagation and absolute determinations of changes in solar radiation indicate the pregnant possibilities of a detailed knowledge of the distribution of ionization in the Earth's outer atmosphere (more recently termed the ionosphere). During the past ten years investigators in various parts of the world have directed their attention to the determination of the distribution of this ionization and to the development of radio methods and technique to obtain this information. The problem is complicated by the variation of ionization with height and location, rapid changes in ionization at a particular height with time, seasonal variations, and other effects whose causes are not immediately apparent. Because of the complexity of the equipment involved in recording the virtual heights of the whole range of ionization obtainable by these methods, the development has proceeded cautiously toward the end of an equipment which will automatically record this information at regular and frequent intervals. Concurrently, less comprehensive investigations of the matter, together with studies of special phases of the problem have been conducted.

Since 1925, following the pioneering measurements conducted by Breit and Tuve at Washington, and by Appleton and Barnett at London, the Department has been interested in the extension of these investigations. Equipment was installed at its Huancayo (Peru) and Watheroo (Western Australia) magnetic observatories for manual multifrequency observations. At present these observatories are being equipped for automatic single-frequency and manual multifrequency registration. Additional equipment will soon be completed which will provide for the continuous automatic multifrequency registration of the virtual heights of the entire range of ionization.

This program during the year was carried on by Berkner at Washington, by Wells at the Huancayo Magnetic Observatory, and by Seaton, beginning in January 1935, at the Watheroo Magnetic Observatory, with Seaton and Stanton as assistants at Washington for short instruction-periods. The shop-work on the power and ionospheric equipment was under the supervision of Huff. These continued investigations have been directed toward the further study of the upper atmosphere and its relation to the diurnal variation, irregular disturbances, and other phenomena associated with the Earth's magnetic field, to radio transmission, and to variations in solar radiation.

RESULTS

Observations—Regular measurements of ionospheric characteristics were begun during January 1935 by the manual multifrequency-technique at the Watheroo Magnetic Observatory. These are the first direct observations of virtual heights and maximum ion-densities of the ionosphere made in the south temperate zone. They represent a notable advance toward the objective of a world-wide determination of the ion-distribution in the upper atmosphere. Ionospheric measurements by the same method were continued at the Huancayo Magnetic Observatory until March 1935. Operations were

then suspended to install the ionospheric recording-equipment and the 110-volt power-system to permit continuous automatic recording, which began in June 1935, on a frequency of 4600 kc. On the basis of this experience, a frequency of 4800 kc. is indicated as most useful for fixed-frequency recording throughout the year at Huancayo.

A fixed schedule of manual multifrequency observation is kept on Monday and Wednesday of each week at both observatories and in part by the National Bureau of Standards at Washington. These measurements involve an hourly sweep through the band of frequencies in which reflections are returned with records of reflection-details at small frequency-increments (usually 100 to 200 kc.). These data give virtual heights, maximum ion-densities, and changes in these quantities in the several regions of the ionosphere and yield a sample from which diurnal, seasonal, annual and long-period characteristics of each ionospheric region, and unusual variations from these values, may be deduced.

Ion-distribution in the upper atmosphere—Observations at the Watheroo Magnetic Observatory show the existence at night of the two major refracting regions (*E*- and *F*-regions) as observed in other latitudes. During the daytime, at small zenith-angles of the Sun, the *F*-region separates into the F_1 - and F_2 -regions (see Year Book 33, 214), which may now be considered as generally world-wide in character. The Watheroo measurements considered with observations of other stations demonstrate that the F_1 - and F_2 -regions exist separately in an approximately circular area under the Sun, merging to form a single *F*-region at the outer limits of this area, where the zenith-angle of the Sun becomes greater than about 45° . Within this area the F_1 -region is depressed below the level of the surrounding *F*-region (about 50 to 70 km. below this level with zenith-angle zero), while the F_2 -region bulges upward 100 km. or more above the F_1 -region. The path of this circular area around the Earth (due to its axial rotation) moves to the north or south as the declination of the Sun changes with season. To a fixed observer, the phenomena change in quite regular manner as the path of this area changes its position with respect to his latitude. With simultaneous observations at Watheroo, Huancayo and Washington, careful investigation of these phenomena have been possible.

The separation of the F_1 - and F_2 -regions varies from day to day. It is sometimes indistinct at even small zenith-angles. Occasionally at very large zenith-angles the separation will be very distinct for one or more days. Incompleteness of the present sample has made it difficult to determine whether such effects are local or general. Maximum separation of these regions is not entirely symmetrical with respect to noon, frequently occurring an hour or two after noon.

Variation of maximum ion-densities—Studies of the maximum ion-densities of the various regions have been continued. Careful examination of the *E*-region critical-frequency (defined as that frequency which just penetrates this region and therefore gives its maximum ion-density) shows no clear-cut effect can be observed by present methods at Huancayo. The maximum ion-density of the *E*-region as observed at Watheroo is ordinarily more sharply defined. Definite evidence of both doubly refracted components

from the E -region has been obtained at Watheroo, and frequently the critical frequency of each component can be observed. Decreases in maximum F_1 -region ion-density of more than 15 per cent have been observed during magnetic disturbances; the correspondence of these decreases with magnetic storms seems to be quite close. In addition, small and comparatively rapid variations—ordinarily not exceeding perhaps 1 or 2 per cent—in the maximum ion-density superimposed on the ordinary diurnal-variation are becoming apparent with improved technique.

Important contributions toward the understanding of the F_2 -region have been made with the commencement of observations at Watheroo and their comparison with the data from Huancayo and other observatories. As pointed out in the report of last year (p. 215), the diurnal variation of maximum F_2 -region ion-density is very erratic as contrasted to the relatively regular variations of the E - and F_1 -regions. The diurnal characteristic is neither symmetrical with respect to noon nor is it duplicated from day to day within limits of perhaps 40 per cent.

The maximum F_2 -region ion-density at Watheroo increased on an average from January to March (1935), followed by a marked decrease. In June these values were well below those observed in January. If these results are representative of conditions observed at Watheroo throughout each year, there will result a double-peaked annual characteristic with maxima near the equinoxes, a major minimum near the June solstice, and a minor minimum near the December solstice.

This is a result similar to that from the observations at the Huancayo Magnetic Observatory—except that the curve is very flat there during the December solstice—and in the Northern Hemisphere (by Schafer and Goodall at Deal, New Jersey, and by Kirby and Judson at Washington, D. C.). This represents a marked asymmetry of the F_2 -region with respect to season and suggests a strong annual effect. No further conclusion can be reached until additional data are available.

Double refraction—The separation of the critical frequencies for the ordinary and extraordinary components at Watheroo averages about 770 kc. for the F_1 -region and 750 kc. for the F_2 -region, respectively. These values are close to the values calculated on the basis of the magnetic field of the Earth at Watheroo at these heights and provide further confirmation of the theory of magneto-ionic double refraction.

Polarization-experiments have been begun at Huancayo. These show the ordinary and extraordinary components of the refracted wave to be plane-polarized for vertical propagation. This is a unique condition because of the location of this station near the geomagnetic equator, where the Earth's field is essentially horizontal (within 2°), confirming Dr. A. L. Green's theoretical conclusions in this respect. As a consequence, each component is received separately on a suitably oriented antenna. A theoretical study of the difference in the path of propagation of the ordinary and the extraordinary rays is partially complete. An understanding of these effects is necessary if variation-measurements of the Earth's field at high altitudes are to be accomplished.

Analysis of data—The analysis of the data for hourly values of minimum virtual-height, character, and critical frequency of each region has been

kept current throughout the year. Additional analyses of the data are applied as they become desirable for particular studies.

Cooperative observations—The cooperative schedule of operations arranged with the National Bureau of Standards for 1934 was continued at both observatories. In conference of Berkner with S. S. Kirby, T. R. Gilliland and E. B. Judson of the National Bureau of Standards, methods of comparison and study of the results so obtained were outlined. It was decided that the material should be subdivided into certain natural classifications, and the study of each classification should be completed in so far as possible before proceeding to the next.

Discussions and conferences—A conference on ionospheric studies was held at the Department April 27, 1935. It was attended by J. P. Schafer, W. M. Goodall and A. M. Skellett of the Bell Telephone Laboratories, E. B. Judson, S. S. Kirby and T. R. Gilliland of the National Bureau of Standards, and Berkner, McNish and Stanton of the Department. Subjects considered were: (1) Correlation of ionospheric phenomena and magnetic activity; (2) correlation of ionospheric phenomena with astronomical phenomena; (3) service of ionospheric investigations to terrestrial-magnetic research; (4) experimental methods; (5) current work of each group; and (6) plans concerning world-wide studies.

An informal meeting on the development and analysis of ionospheric studies was held at the Deal, New Jersey, experimental station of the Bell Telephone Laboratories, June 18 and 19, 1935, between J. C. Schelleng, J. P. Schafer and W. M. Goodall of the Laboratories and Berkner of the Department.

Dr. A. L. Green of the Australian Radio Research Board visited the Watheroo Magnetic Observatory March 27, 1935, to study the methods of ionospheric investigation of the Department and to discuss cooperative arrangements. He expressed a desire that close cooperation with the Watheroo and other observatories of the Department might be established when work is begun in Sydney and in New Zealand.

INSTRUMENTAL DEVELOPMENT

Experimental and developmental work at Washington—Experimental and testing work has been conducted at the Department's Kensington field-station, licensed by the Federal Communications Commission as general experimental station W3XI. The site of several acres, one mile south of Kensington, Maryland, near Washington, has been made available through the continued generosity of Colonel M. K. Barroll, U. S. A. (retired), who for a number of years has shown unusual interest in this work. The field-laboratory, power-circuits and antenna-poles were made available through cooperation of the National Bureau of Standards, by whom this site was previously used.

Development of equipment—The first step toward a final continuous automatic multifrequency-equipment was completed during the year. This consisted of a photographic recorder with associated receiving- and power-equipment suitable for automatic single-frequency and manual-multifrequency recording. It is designed for economical operation on the limited

power-supply available at the observatories. The first equipment of this type was completed in the instrument-shop and sent to the Huancayo Magnetic Observatory. The equipment it replaced was returned to Washington and its modification for Watheroo is well advanced.

Experimental work on the continuous-automatic multifrequency-equipment to operate with the recording equipment has been well advanced during the year. It is found possible to operate such equipment at practically full output and sensitivity over the entire range of desired frequencies (600 to 16,000 kc.) with four automatic transmitter-controls (using two antennas) and with complete elimination of receiver-controls. The electrical design of the equipment is virtually complete and construction of an operating model incorporating the mechanical controls has been begun.

Installation of the continuous recording-equipment has required additions to the power-supply at the observatories to make continuously available about one kilowatt at 110-volt, 60-cycle alternating-current. The frequency of supply must be carefully controlled as it forms the standard for the virtual-height measurements. In collaboration with the Electric Speciality Company, a standard-speed controller utilizing grid-controlled gas-discharge tubes has been developed for maintaining a 1-kw. rotary converter at constant speed, thus furnishing the necessary frequency-control.

Development of technique—Much time has been devoted to improvement of technique of observing and recording to improve the character and resolution of the records. A study was conducted at Kensington prior to the completion of the recording equipment. A report of these results, together with detailed instructions concerning the installation, operation and maintenance of the apparatus was incorporated in a "Manual of instructions for operation and maintenance of automatic multifrequency recording-equipment."

MAGNETISM AND ATOMIC PHYSICS

The general objective of the various researches carried out in the Department's experimental laboratory has been the formulation and investigation of basic aspects of magnetism through studies in fundamental physics. This long-term program has been concerned in recent years with a pioneering attack on the atomic nucleus by high-voltage methods, an objective shared by several other laboratories in this country and abroad. Tuve, Hafstad, Dahl and Brown comprised the experimental staff during the report-year. Laboratory problems more immediately geophysical in nature have arisen at various times since the initiation of the ionospheric studies in 1924-25, and a project of this type which looks toward an experimental study of the upper-air region above 30 kilometers and below the ionosphere, using an interrupted searchlight-beam and tuned amplifier, was inaugurated shortly before the close of the year. The restricted size of the experimental group makes it necessary to avoid diffusion of effort, however, and even the present main program in nuclear physics is limited to a few major items.

The broad significance of experimental and theoretical information in the field of nuclear physics is now generally recognized. This new field is being rapidly developed, although many simple and far-reaching questions are yet all but unapproached. Following a fruitful period of discovery and survey,

various detailed and quantitative investigations, both experimental and theoretical, are now being made by a growing body of investigators. During this report-year, two contributions from the Department's laboratory have been of particular interest, one presenting a study of various resonance-transmutations by protons and the other giving new data on the carbon-reactions, relating to the correction of the mass-values of the lighter atomic nuclei.

HIGH-VOLTAGE METHODS

Probably the most important development of the year in the experimental work was the integration of the Department's nine years of high-voltage experience into the formulation of a comprehensive technical plan for equipment and procedure to encompass the whole range of nuclear investigations in the region below cosmic-ray energies. This plan is the direct result of an effort on the part of the Director to assess the present and future positions of this phase of the Department's activities in relation to other developments. A critical examination of all known possibilities in respect to the technique of nuclear-physics investigations showed the fact, not entirely apprehended before, that the Department's work has now provided a sound basis for a full-scale development which eliminates the necessity for technical compromise—a necessity hitherto universally accepted because of the extreme difficulty of working in this new region of very small dimensions and very high energies. Major features of the plan are a high-voltage generator and vacuum-tube installed within a large spherical pressure-tank and insulated by compressed air. The Department's present equipment reaches a maximum of slightly more than one million volts, which is just enough to make a beginning in studies of nuclear interactions. The same is essentially true of any equipment limited to the region below several million volts, although it can be said with assurance that the possibilities opened up by such an installation can not be exhausted in two or three years of research. However, the importance of, and the ultimate necessity for, extending the investigations over a wide voltage-range can not be questioned; the potential barriers of all but the very lightest elements undoubtedly exceed a height of five-million volts, and the average binding-energy of successive individual nuclear particles is known from mass-values to be seven- to eight-million electron-volts, while even higher energies are of very great importance in various collisional and non-capture problems. The proposed pressure-sphere generator and associated high-voltage tube are designed to operate at steady and controllable potentials of either sign higher than ten-million volts above ground, and to provide ample currents for X-ray studies and for other technical requirements. The characteristics to be desired and the quantitative requirements to be met, together with the highly important matters of flexibility and adaptability to meet the varied demands of a whole array of different applications, are aspects of the design based on the Department's direct experience. The working characteristics and behavior of such an equipment, as well as the magnitude of the attainable voltage, may be considered as already established by reason of the Department's experience with each of the various technical factors. Only a relatively limited and immediate extrapolation in respect to any one factor is involved, except of course in

respect to the desired objective of total voltage. The plan is unexpectedly made very practical by recent developments in the construction of high-pressure gas-holders.

The numerous discoveries and developments in fundamental physics during the past five years serve to illuminate and emphasize the opportunity for exploring a whole new domain of physical research which this synthesis of the Department's efforts and experience represents. Such an installation, if realized, would constitute a new scientific instrument whose potentialities for enlarging understanding of the material world may be compared without hesitation to those of the first large telescopes. This instrument may be depended on in the same way to serve a whole generation of investigators, and with an expanding range of usefulness and importance.

A project similarly concerned with the future growth of our knowledge concerning magnetic and electric interactions on the smallest scale and hence at the highest energies—the subject-matter of nuclear physics—and in a similar way by the development of new technique, is the cooperative effort, now in progress, of the Department's staff with Professor J. W. Beams and Dr. L. B. Snoddy of the University of Virginia. Its aim is to explore the possibilities of the "wave-front" method for producing very high energy-particles, proposed and already partly tested by Beams and Snoddy. Among the twelve distinct methods for high voltage (high-energy) attack which have been suggested and more or less tested during the past eight years this method alone gives any promise of being ultimately capable of extension into the actual region of cosmic-ray energies above 20-million volts. This cooperative project should determine its potentialities and the rôle the method might play in a comprehensive plan of attack covering the whole range of nuclear energies.

NUCLEAR-PHYSICS RESULTS

Data were obtained during this year as before on a considerable variety of problems, and again many of the observations were subject to modification or were considered incomplete by themselves because of the tremendous variety of factors already known to be of importance in experimental work on nuclear transmutations. However, during the year two or three general projects were brought to a degree of completion sufficient to warrant their publication, and other material was completed except for certain necessary check-measurements and the task of assembly and discussion of the data.

Artificial radioactivity of carbon—The pronounced differences in the observations on this phenomenon obtained in Cambridge, in Pasadena, and in the Department's laboratory were noted in last year's report. Because the effect due to protons was not detected and was shown to be less than 1/8000 of the deuteron-effect at 1000 kilovolts, the Department's data suggested that contamination by deuterons might be the cause of the proton-effects at lower voltages, reported to be of a magnitude comparable to or exceeding the deuteron-effects observed. As suggested by Professor Lauritsen at the Berkeley meeting (June 1934), however, the marked difference in the variation of the deuteron-effect with voltage from that of the proton-effect, that is, the marked difference in the two "excitation-functions," proved to be the correct explanation. At 900 kilovolts a real proton-effect was found in August

1934 by the Department's investigators; the magnitude of the effect was under the previous limits of detection, being less than $1/10,000$ of the deuteron-effect. Proceeding to lower voltages the deuteron-effect, always larger than the proton-effect, was found to vary nearly exponentially with voltage, whereas the proton-effect was found to occur only for a very restricted range of proton-speeds, exhibiting the striking characteristics of a *resonance*, transmutation-process. Indications of a multiplet structure, perhaps of two "lines" at 420 and 480 kilovolts, instead of a single resonance-peak were obtained. The proton-effect in this case is an example of radiative capture, and its characteristics should be quantitatively predictable from quantum theory. Calculations on this point were carried out by Professor Breit and Dr. Yost for comparison with the laboratory data.

Other resonance-transmutations by protons—The striking beauty and simplicity of the carbon-resonance results led to an examination of several other known proton-effects in a search for resonances. The gamma rays from fluorine and those from lithium show resonance-characteristics. Fluorine exhibits three resonance-"levels," at approximately 320, 600 and 750 kilovolts, and lithium shows two, at about 450 and 850 kilovolts. Although lack of a suitably established voltage-scale means that the voltages given for these resonance-effects as yet refer to the rather arbitrary voltage-calibration (proton-range measurements, sphere-gap indicator) previously adopted in the Department's work for use until a reliable voltmeter is developed, the abrupt nature of the response at these various resonance-levels provides an admirable means for intercomparison of the voltage-scales used in different laboratories. Such a comparison will be of immediate value in view of the importance of excitation-functions and the difficulty of referring numerous types of observation to an absolute intensity scale.

The carbon-reactions and the corrected mass-scale—Reaction-energies and mass-values as determined from transmutation-data have not been in reasonable agreement with the values deduced from mass-spectrograph data, except for the lithium-disintegrations, and some of the disagreements have constituted rather bizarre difficulties, notably in the case of certain beryllium-reactions. By a slight alteration of the helium-oxygen ratio given by Aston, Professor Bethe of Cornell in April 1935 brought nearly all available data into a consistent state. A crucial feature of his reasoning, based on transmutation-data, was the assignment of the protons and gamma rays emitted by carbon under deuteron-bombardment to two different processes, instead of assuming that they were two steps in a single transmutation-process, as was consistent with the older carbon mass-values. In addition to the proton-emission there occurs an alternative reaction, giving rise to the emission of neutrons but involving the same initial and final isotopes, and it was consequently evident that even a rough measure of the energy of these neutrons would distinguish between the reaction-energies of three- and of six-million electron-volts predicted by the new and by the old carbon mass-values, respectively. Such measurements were carried out during May, along with various checks and control-determinations especially relating to the carbon gamma-rays, with a final result distinctly contrary to the old mass-values and near to that predicted by Professor

Bethe's carbon masses, although differing from it by about 0.6-million electron-volts, an amount rather larger than the apparent error-limits of the determination might indicate. It thus appears that the new mass-scale is much more satisfactory than the old, although some slight modifications will still be required.

Carbon gamma-rays—The comparatively extensive measurements made on the carbon-reactions have brought out a singular fact in connection with the gamma rays emitted when this element is bombarded by deuterons. It appears from the relatively high yield (about 2 quanta per 10^6 deuterons) and the high quantum-energy (3.5 to 4 million electron-volts—it is not certain that all quanta have this maximum energy, however) that the familiar but crude wave-mechanics picture of charged particles penetrating a potential barrier from outside and from inside the nucleus is not sufficient to describe the process giving rise to these carbon gamma-rays, but that a more accurate representation of the overlapping wave-functions is required, effectively giving rise to a higher probability of neutron-capture and proton-emission than the crude penetration-calculations would predict. Further investigation of this question, especially in respect to the excitation-function for the gamma rays alone (using cloud-chamber observations to prevent errors due to the known presence of neutrons) was in progress as the report-year ended.

Other data—Among the observations which have been made and may be considered as nearly complete, but which are held in abeyance pending the completion of a reliable voltmeter for use in the final check-measurements, it may be of interest to mention a few of the more important ones. Deuterons on deuterons: Excitation-function and absolute yield for proton-emission, proton-range versus voltage, neutron-yield and neutron-energy, absence of gamma rays, straggling of proton-ranges using a gas target. Deuterons on carbon: Excitation-function and yield for proton-emission, e/m for emitted protons, proton-range versus voltage, neutron-yield and excitation-function (by radioactivity of N^{13}), gamma-ray yield and partial excitation-function (by cloud chamber, free from neutron-effects), positron spectrum and decay-period (N^{13}), limits on possible long-range proton-yield, contamination-studies. Protons on carbon: Positron-spectrum and decay-period (N^{13}), gamma rays by radiative capture. Deuterons on beryllium: Identification of emitted protons by e/m ; absence of negative proton-emission, limits on negatron-yields (excluding certain reactions), yields and energies of gamma rays and neutrons, straggling of long-range protons. Deuterons on oxygen: Yield and range of "8-cm group" versus voltage to 1000 kv, intensity and energy of gamma rays, contamination-studies. Protons on lithium: Excitation-function for 8-cm alpha-particles to 1000 kv, absence of special particle-groups at resonance-peaks, yield and energy of gamma rays. Protons and deuterons on fluorine: Yields and ranges of alpha particles, yields and energies of gamma rays. If the 1000-kilovolt resistance-multiplier, which is under development as the report-year ends, proves a satisfactory means for accurate voltage-measurement, especially for calibrating the arbitrary voltage-scale already used, these data, taken with a strictly mono-energetic ion-beam will comprise an adequate basis for quantitative theory.

EXPERIMENTAL TECHNIQUE

Besides the general consolidation of the Department's high-voltage technique as expressed above for future development, certain specific items of technique were developed or enlarged upon during the year. Of these, two were of particular importance.

Capillary-arc ion-source—An experimental difficulty of considerable magnitude in nuclear-physics investigations has been that of producing intense beams of positive ions, especially the refractory hydrogen- and helium-ions required for such work, under suitable conditions (gas-pressure, power-input, heavy-hydrogen consumption, practicable pump-speeds) for high-voltage operation. Based on the suggestion by Dr. F. L. Mohler of the National Bureau of Standards that a low-voltage arc confined in a capillary should be intensely ionized and give high current-density to an adjacent probe, a new type of ion-source was evolved which gives positive ion beam-currents exceeding one milliamperere (total, of mixed ions) with a power-consumption of less than 300 watts and with the intensity and focusing properties of the beam minutely under control. The gas-consumption and pumping requirements of this source are modest, and a practical means for obtaining even much larger currents (if they can be utilized) is indicated. Such a device may prove of value in isotope-separation, especially in conjunction with the complementary information on focusing which was obtained. The percentage of atomic hydrogen ions with this source as yet is less satisfactory than might be desired, being only 20 to 25 per cent (tank hydrogen) where the best previously attained, with old-type sources giving only a few microamperes, might have been as high as 50 to 60 per cent. Using magnetic analysis, however, pure proton-currents exceeding 100 microamperes are now readily available if the tube-dimensions and voltage permit them to be focused on the target.

Focusing of positive ion-beams—As pointed out in previous annual reports, an important part of the Department's contribution to the field has been the development of vacuum-tubes which operate reliably at very high voltages and which focus on the distant target practically the whole of the input-current which is projected into the electrode-system of the tube. To define more clearly the relative importance of the various factors entering into the important and hitherto obscure matter of the propagation and focusing of such ion-beams by a system of tube-electrodes having various possible characteristics, an empirical investigation of the numerous parameters of this problem was made, utilizing the intense ion-streams available with the new capillary-source. The unpredictable importance of space-charge and aberration-effects made such an examination highly desirable, and the data obtained are sufficient for quantitative design purposes on matters hitherto left to chance. It appears that almost any system of cascade tube-electrodes can be made to focus a considerable part of the input ion-current, provided the remaining parameters (usually voltage per section and distances of source and target) are adjusted within proper limits. However, to obtain a good spot-focus including the whole of an intense ion-beam the limitations are rather definite, and it is of interest that a design and technique very similar to that previously utilized in the Department's work is desirable and, to a considerable extent, necessary.

High-voltage technique—In addition to a paper giving the results of the above special projects, a complete description of the Department's high-voltage equipment, experience and technique, covering a period of nearly five years, was prepared for publication and was in the hands of the printer (Physical Review) at the end of the report-year.

THEORETICAL-PHYSICS CONFERENCE

A Conference on Theoretical Physics to coordinate current theoretical researches was held in Washington April 19 to 21, 1935, under the joint auspices of the George Washington University and the Carnegie Institution of Washington, acting through this Department. Invitations were extended to a small representative group of active theoretical physicists to discuss informally those current problems which they judged most important. This initial meeting was devoted to certain theoretical problems in the rapidly expanding field of nuclear physics. Devoted solely to the clarification of the current status of the subject and to discovering the profitable directions for immediate attack, these sessions were subsequently evaluated by those present as uniquely effective in advancing the progress of their own researches. Meetings of this special type deserve support as an instrument for facilitating the progress of theoretical physics. Two problems confront such a program: (1) The difficulty of sufficiently restricting the number present to avoid unwieldiness without thereby causing misunderstandings through lack of appreciation that such a procedure is necessarily arbitrary; (2) the problem of making available in some way the benefit of these discussions to the large group unable to be present. Progress in any sector ultimately benefits all and the evident usefulness of such meetings should not be sacrificed for lack of an equitable mechanism for carrying them out.

At this initial Conference about 35 representatives of 20 universities and research-organizations were present. Five sessions were held on the three days, four of them devoted to more or less specific topics as follows: (a) General nuclear model; (b) nuclear transformations; (c) the process of beta-disintegration; and (d) effects of high-energy radiations. In view of the Institution's interest in the fundamental aspects of physical science, as well as in connection with the Department's researches in nuclear physics and magnetism, the Institution's cooperation in a series of conferences of this type is particularly appropriate and effective.

COOPERATION IN NUCLEAR PHYSICS AT UNIVERSITY OF WISCONSIN

Professor G. Breit of University of Wisconsin continued as research associate and consultant in the nuclear-physics program. The following paragraphs summarize briefly the theoretical and experimental work done by him and his assistants.

Radiative capture of protons by carbon and other similar reactions—F. L. Yost collaborated with Dr. Breit in this research. The yields observed can be fully accounted for on the present theory. There is some difficulty in understanding why the observed yield is as small as it is. The consideration of the resonance-phenomenon involved shows that for thick targets the total

yield does not depend critically on the penetration of the nuclear barrier and that therefore one may hope to observe resonance-reactions with moderate voltage for heavier nuclei.

Computation of wave-functions in a repulsive Coulomb field—Tables for angular momenta $(0,1)\hbar$ are now being prepared for publication by Breit, Wheeler and Yost. These tables show the crude nature of the approximations usually made for these functions.

Quantitative comparison of theory with experiment for yields of alpha particles in bombardment of Li with H^1 and H^2 —The results show that estimates made by Cockcroft and others are inapplicable.

Calculation of fine and hyperfine structure for Na—The theory was improved to give better agreement with the fine structure and more consistent values of nuclear magnetic moments. The theory is not yet good enough to claim certainty in the values of nuclear moments.

Experimental—A rectifier set for 250 kv. was constructed by Heydenburg, Zahn and King with advice from Breit. Observations on the thick-target yield of $(Li^7 + H^1)$ were made from 50 kv. to 200 kv. These observations join nicely with those of Herb, Parkinson and Kerst.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

The activities of the Section of Land Magnetic Survey have been directed largely, as in past years, toward studies pertaining to secular changes in the Earth's magnetic field. Adverse economic conditions and decreased personnel continue to necessitate curtailment of field-operations and relatively few data have been collected through work of one Department observer in Africa and through cooperative arrangements in China, in Australia, and in Antarctica. The personnel of the Section during the year included Green, Acting Chief of Section, Duvall, and Mansfield on field-duty; Wallis and Johnson also gave some time to the Section.

On account of world economic conditions but small progress could be made toward realizing the plans of the International Association of Terrestrial Magnetism and Atmospheric Electricity to increase the number of magnetic observatories, especially in the Southern Hemisphere, and for a network of selected magnetic repeat-stations for investigations of secular variation. The stations occupied by Mansfield in Africa during the year were in large part selected from the Association's list. This expedition will supply secular-variation data for southern, eastern and part of northern Africa, but the need for similar data along the entire west coast is becoming acute. Australia and the entire Indian Archipelago are also regions where the need is great. The Aerial Geological and Geophysical Survey of Northern Australia is about to begin operations extending over three years and covering 30,000 square miles; its activities will include magnetic observations, and magnetic equipment and instruction will be supplied by the Department.

The total number of localities occupied for magnetic work during the year is 81, distributed as follows: Africa 27, Alaska 1, Australia 9, Central America 4, China 16, Easter Island 1, Galapagos 1, Little America 21, and

New Zealand 1. With the exception of Africa, the regions from which data have been collected are so scattered and the number of stations is so few that no new discussion concerning possible changes of trend in any of the elements was undertaken.

Derivation of declination values at track intersections of the *Gahlee* and the *Carnegie* in the Pacific for the purpose of determining secular variation in that element was continued by Duvall throughout the year.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Brief accounts of field-operations referred to above are given in more detail in the following paragraphs.

Africa—Mansfield continued the expedition begun just before the close of the preceding report-year. Observations were made, and in most cases auxiliary stations were established, at the following points: Orange River, East London, Uitenhage, Durban, Lourenco Marques, Pessene, Pretoria, Mafeking, Bulawayo, Livingstone, Victoria Falls, Salisbury, Beira, Mozambique, Dar es Salaam, Zanzibar, Tabora, Kampala, Entebbe, Nairobi, Mombasa, Aden, Port Sudan, Suez, Tripoli, Tunis, and Algiers. This expedition was delayed somewhat by an unavoidable accident to magnetometer and inductor No. 16 with which it was begun and necessitated a journey of about 1200 miles to secure magnetometer and inductor No. 18 on loan to the British East Africa Meteorological Service at Nairobi. Our arrangements with Director A. Walter of that Service for cooperative work in British East Africa were thus temporarily interrupted pending the loan of another instrument for his use. Thus far results from eight stations occupied by the Service have been received.

As was the case during the preceding year, the cooperative work with the University of Cape Town was continued by the loan of magnetometer and inductor No. 17, used for absolute control at the Cape Town Observatory, established for the Polar Year and which is being continued.

The completed cahiers from the 15 stations occupied by Dr. E. C. Bullard in British East Africa during the spring of 1934, mentioned in last year's report, will, when received, materially add to the secular-variation data for the eastern half and northern part of Africa.

Asia—Cooperative work in China under the direction of F. C. Brown, formerly an observer of the Department and now connected with the American Church Mission at Hankow, assisted by Dr. C. T. Kwei of the Central China College at Wuchang, was continued. These observers, alternating each month, kept up periodic observations at the Wuchang Station. Double sets of observations were made each month, the times being so arranged that these sets would fall approximately at the time of the maximum and minimum values for each element. During September to November 1934, Brown completed an expedition to Western China and the borders of Tibet. Observations were obtained at 22 stations in 15 localities; seven were repeat-stations. The localities occupied were Chengtu, Yaan, Hwangnipu, Nitow, Luting, Kangting, Yinkwanchai, Tzetati, Mosimien, Fulin, Tawei, Omei, Loshan, Ipin, and Chungking. At the close of the year Dr. Kwei was just beginning an expedition to Southern China.

Antarctica and the Pacific—The cooperative work with the Second Byrd Antarctic Expedition in Antarctica was under the general direction of Dr. T. C. Poulter and the immediate supervision of Dr. E. H. Bramhall, assisted

by A. A. Zuhn. Magnetograph records with the usual absolute observations were obtained from February 12, 1934, to February 4, 1935. In addition, 21 stations were occupied during two field-trips as follows: (a) The tractor Plateau Party observed during October 22, 1934, to January 1, 1935, 17 stations between latitudes 78° and 82° south and longitudes 149° and 164° west, at 15 of which the three magnetic elements were observed but only declinations at the other two; (b) Eastern Party made four stations between November 6 and December 10, 1934, going as far east as $76^{\circ} 40'$ south and $145^{\circ} 34'$ west, determining the three elements at two, but only declinations at the other two.

Observations of magnetic declination were obtained at Easter Island on the outward journey of the Expedition. On the return voyage a station was established on Albemarle Island of the Galapagos Group and observations were made in the Canal Zone.

Australasia—Observations at eight stations in South Australia have been received from Director Dodwell of the Adelaide Observatory. These were Ceduna, Yalata, Flinders, Port Victoria, Goolwa, Strathalbyn, Kuitpo Forest and Nairne. The field-work was done by A. E. Markey of the Observatory staff using C.I.W. theodolite-magnetometer No. 6 and Dover dip-circle No. 226, the latter the property of the Observatory.

The usual control-observations for magnetograph base-lines were maintained at the Watheroo Magnetic Observatory.

Intercomparisons of the Department's magnetic instruments used by the Second Byrd Antarctic Expedition were made at the Amberley Station of the Christchurch Observatory in New Zealand.

North America—There has been very little occasion for comparison work during the year. The Department's sine-galvanometer No. 1 was set up at the Cheltenham Magnetic Observatory, where it is to become the standard for horizontal intensity, and a series of test-observations was made. A final comparison at Cheltenham between this instrument and the Department's standard magnetometer No. 3 will be made in July and August 1935. Intercomparison and restandardizations at our Standardizing Magnetic Observatory in Washington of field-instruments including those used on the Second Byrd Antarctic Expedition—universal magnetometer No. 21, dip-circles Nos. 222 and 241—magnetometer No. 9 prepared for loan to Apia Observatory after being sent to Watheroo for comparison there, and earth-inductor No. 171 and dip-circle No. 242 used at the College-Fairbanks and Point Barrow Polar-Year stations.

Four cahiers of observations made by Lieutenant J. C. Woelfel of the United States Hydrographic Office in Central America during the preceding fiscal year and one cahier of observations made in Alaska in July 1934 were received October 29, 1934. The stations occupied were as follows: Puerto Armulles and Puntarenas (Panama), San José B and San José D (Costa Rica), and Attu (Alaska).

South America—Secular-variation data were obtained through the control-observations made at the Huancayo Magnetic Observatory.

OBSERVATORY-WORK

In the Section of Observatory-Work, Johnston, McNish, Forbush, Ledig, and Miss Balsam had part-time assistance from Scott (to August 31, 1934), Ennis and Hendrix. The members of the staff engaged at the observatories are mentioned in the respective reports.

OPERATIONS AT OBSERVATORIES

The operations during the report-year at the observatories of the Department and at those with which the Department cooperated are summarized below:

Watheroo Magnetic Observatory, Western Australia—The Watheroo Magnetic Observatory is situated in latitude $30^{\circ} 19' 1''$ south and longitude $115^{\circ} 52' 6''$ east of Greenwich, 244 meters (800 feet) above sea-level.

The la Cour rapid-running and Eschenhagen magnetographs were operated continuously through the year. The weekly absolute observations for control of base-line were made regularly. Monthly scale-value determinations by Helmholtz coil of the la Cour magnetograph gave consistent results; the average scale-values during 1934 for the horizontal-intensity and vertical-intensity variometers were 4.69 and 2.40 gammas per mm., while the maximum departure of the individual values from the mean was 0.5 and 4 per cent, respectively. Monthly magnetic scale-values of the Eschenhagen horizontal-intensity variometer agreed within 0.5 per cent and the mean value for the year was 2.65 gammas per mm. Monthly during 1934, through November, both magnetic and electric scale-values were observed for the Eschenhagen vertical-intensity variometer; the mean scale-value for the 11 months by each method was 4.33 gammas per mm. From December 1934, scale-values of the Eschenhagen vertical-intensity variometer have been determined by the electrical method only. The Crichton-Mitchell vertical-intensity variometer was in operation through the year although toward the end of 1934 frequent losses of trace for short periods were occasioned by clock-failure; the clock is being replaced. The preliminary mean values of the magnetic elements for all days of the year 1934, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: Declination $-3^{\circ} 47' 8''$; horizontal intensity 0.24669 C.G.S. unit; vertical intensity -0.51341 C.G.S. unit; and inclination $-64^{\circ} 20' 2''$. The preliminary values for the annual changes in the magnetic elements based on these values and on the *final* values for 1933 are: $+5' 6''$ in declination; $+10$ gammas in horizontal intensity; -33 gammas in vertical intensity; and $-0' 4''$ in inclination. The standard magnetometer D.T.M.C.I.W. No. 7 was compared with magnetometer D.T.M.C.I.W. No. 9 which is being loaned to Apia Observatory, Western Samoa.

Continuous records of earth-potentials, for derivation of diurnal variations of earth-currents, were made throughout the year over the system of electrodes as described in previous reports. Complete records were secured on 349 days of the year 1934.

Air-potentials were recorded continuously with the standard potential-gradient apparatus as in former years. The usual monthly "reduction-factor" determinations were made; the mean reduction-factor for 1934 is 1.10 with an extreme range in individual monthly determinations of 0.07. This is in close agreement with the previous yearly values which were 1.12, 1.11, 1.12, 1.11 and 1.11 for 1929, 1930, 1931, 1932 and 1933, respectively. The mean annual value of air potential-gradient for the calendar year 1934 as derived from 183 complete days is 84 volts per meter using the reduction-factor 1.10.

Positive (λ_+) and negative (λ_-) air-conductivities were recorded with the usual regular control-observations. The preliminary average annual values for 1934 for a total of 217 complete days resulting from the monthly means

are, in units of 10^{-4} electrostatic unit: λ_+ , 1.98; λ_- , 1.76; $(\lambda_+ + \lambda_-)$, 3.74; (λ_+/λ_-) , 1.12.

The narrow-sector directional atmospheric recorder, on loan from the Australian Radio Research Board of the Council for Scientific and Industrial Research, which had been out of commission during a portion of the previous report-year, was reassembled during July and August 1934, and traces have been obtained nearly continuously since that time. The records are sent periodically to Melbourne for analysis. Much time was spent on this equipment but it is considered that the traces being obtained justify this attention. Arrangements are being made to send by radio to Melbourne a brief daily report in code on "atmospherics" character.

At the beginning of the present report-year the ionospheric equipment was under test. Curedale, who was in charge of this work, left the Observatory at the end of August 1934, and from that time until the arrival of Seaton from Washington in January 1935, the apparatus was not in use. By the end of January 1935, however, the ionospheric equipment had been thoroughly tested and calibrated, and since then determinations of layer-heights and critical frequencies have been made biweekly in accordance with the regular schedule. Preliminary reductions of the observational data were made and forwarded to Washington at regular intervals. During the initial stages of this work the transmitter and receiver were located in the same building as the 110-volt power-plant; in order to eliminate the background of mechanical and electrical noise the apparatus was, in April 1935, moved to the small radio cabin, which was renovated for this purpose, the cabin being about 210 feet due north of the power-house. This new location gave substantial improvement in observational conditions. The use of the higher-powered transmitter of the ionospheric equipment for communication has enabled direct two-way contact to be made with numerous amateur stations in the United States and several reliable channels for the prompt transmission of reports and data were developed. A further advantage of this direct communication is that it has enabled us to conform with the Australian Radio regulations which forbids the relaying of messages within the Commonwealth; a special dispensation was granted to the Department to do this pending the installation of the present equipment and due acknowledgment is here made of the courtesies extended. Grateful acknowledgment is also due H. M. Cooper of radio station *VK5HG*, Adelaide, for his unremitting care and assiduity in relaying our messages during the past six years. Experiments have been made in transmitting antennae and the type now being used, a vertical half-wave antenna, has proved so far the most satisfactory.

Observations of solar eruptions with the Hale spectrohelioscope were continued throughout the report-year until early in May 1935, when the driving clock was in Perth for a few weeks, being replaced by a more robust movement. Early in 1935 a pair of aluminized celostat mirrors was received from Mount Wilson and installed; about the same time some modifications were made in the observational procedure on advice from the Meudon Observatory, which conducts the world-wide scheme of cooperative solar observation.

The usual meteorological observations, including nuclei-count, were made daily and all the self-recording meteorological instruments were kept in continuous operation. Data were supplied monthly to the Commonwealth Weather Bureau in Melbourne as in former years.

There was much constructional and improvement work done. Among numerous items were: The interior of the small radio cabin was relined and furnished and a brick fireplace and chimney built; a 2000-gallon tank

mounted on a stand of suitable height has been installed at the power-house to provide a constant change of water in the radiator of the 110-volt motor-generator; the earthing wire-screen on the louvers of the Atmospheric-Electric Observatory was entirely renewed in separate vertical panels; underground power-cables were laid from the power-house to the small radio cabin, now the ionospheric laboratory. The maintenance of buildings and of road to Watheroo received requisite attention.

Parkinson continued as observer-in-charge throughout the year. Cure-dale left at the end of August 1934, and was replaced by Seaton, who arrived January 12, 1935. Culmsee and Hogan continued as junior observers. Caswell was electrician and mechanic until the end of 1934, when he left after over six years of efficient service; he was replaced temporarily by Stephens, who left at the end of May 1935, his place being taken by Masters on June 1. It is only through the splendid cooperation and efficiency of the staff that the heavy program was successfully maintained.

The Observatory was honored April 19-20, 1935, by a visit from Dr. F. P. Keppel, President of the Carnegie Corporation of New York, accompanied by Mrs. Keppel. Dr. Keppel made a complete inspection of the buildings and equipment and was pleased to make favorable comment on all he saw. Other visitors during the report-year included: Mr. H. B. Jackson, K.C., Chairman of Directors of the West Australian Newspapers, Ltd.; Mr. F. A. Lording, Manager of the Atlas Assurance Company, Perth; Mr. Kirkby, Inspector of the Postmaster-General's Department; Dr. A. L. Green, Physicist of the Radio Research Board, Sydney.

The support and cooperation of various State and Commonwealth Departments was continued and grateful acknowledgment is hereby made to the following in particular: Mr. H. P. Brown, C.M.G., and Mr. J. Malone of the Postmaster-General's Department, Wireless Branch, Melbourne, and Messrs. Scott and Turnbull of the Radio Inspector's Office, Perth, for assistance and the extension of departmental privileges in the Observatory's radio program; the Department of Trade and Customs of the Commonwealth of Australia for assistance in the matter of importation of equipment; Professor A. D. Ross of the University of Western Australia for continued interest and assistance in the activities of the Observatory. The Department mourns the loss, by the death of Senator Sir Walter Kingsmill, of a very valuable friend of the Observatory ever since its inception.

Huancayo Magnetic Observatory, Peru—The Huancayo Magnetic Observatory is situated in latitude $12^{\circ} 02' 27''$ south and longitude $75^{\circ} 20' 4''$ west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 meters (11,000 feet) above sea-level.

The la Cour rapid-running and Eschenhagen magnetographs were operated continuously through the year. The weekly absolute observations for control of base-line were made regularly. The monthly scale-value determinations for the la Cour magnetograph were made by Helmholtz coil. Scale-values for the horizontal-intensity variometer of the Eschenhagen magnetograph were measured monthly by small magnet and by large magnet from March 1934 to January 1935. Scale-values of the vertical-intensity variometer of the Eschenhagen magnetograph were obtained by Helmholtz coil at frequent intervals from October 1933 and by large magnet monthly from October 1933 to January 1935. The scale-values by the two methods differ only by the error of observation.

At the end of January 1935 the Eschenhagen magnetograph was elevated 5 cm. so that Helmholtz coils might also be placed around the declination and horizontal-intensity variometers; since then electrical scale-value ob-

servations have been made weekly. They are made thrice weekly on the vertical-intensity variometer. The preliminary mean values of the magnetic elements for all days of 1934 as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: Declination $+7^{\circ} 18.1$; horizontal intensity 0.29622 C.G.S. unit; vertical intensity $+0.01107$ C.G.S. unit; and inclination $+2^{\circ} 08.5$. The preliminary values for the annual changes in the magnetic elements based on these values and on the *final* values for 1933 are: -3.3 in declination; $+8$ gammas in horizontal intensity; $+32$ gammas in vertical intensity; and $+3.8$ in inclination.

Air-potentials were recorded continuously with the standard potential-gradient apparatus. Ten determinations during 1934 of the reduction-factor to reduce recorded volts to those at an undisturbed point one meter above the ground gave the average value of 1.16, the same as in 1933. The preliminary mean-value of the potential gradient derived from 146 selected days in 1934 was 51 volts per meter—47 days in the wet season averaged 50 volts per meter and 99 days in the dry season averaged 52 volts per meter. The preliminary mean-value for 1933 was 47 volts per meter.

Positive and negative air-conductivities were regularly recorded. The preliminary mean value for 145 selected days in 1934 was 3.31×10^{-4} electrostatic unit for the positive conductivity and 3.68×10^{-4} electrostatic unit for the negative conductivity. The twelve monthly values of total conductivity for 1934 in units of 10^{-4} electrostatic unit were 8.89, 7.13, 6.46, 8.13, 6.20, 7.06, 5.87, 6.27, 6.21, 7.20, 6.76, and 7.60.

The measurement of earth-current potentials was continued. The recorder was stopped during periods when nearby thunderstorms occurred, thus preventing damage which might have caused serious interruption.

In November 1934, aluminized cölostast mirrors for the spectrohelioscope received from Mount Wilson Observatory were installed. After a preliminary experimental period, regular observations of solar prominences and spots were begun in March 1935. In agreement with the general program of worldwide spectrohelioscope observations outlined by Commission No. 11 of the International Astronomical Union, the observations are made daily over two half-hourly periods beginning at $15^h 30^m$ and $16^h 30^m$ Greenwich mean time.

Of the seismological equipment, the two Wenner horizontal-component seismometers were operated throughout the year. The seismograms were forwarded to Washington twice each month and the associated control-records at the end of each month. In addition, all important disturbances were reported promptly by radio. Upon receipt of a new driving-clock for the Benioff seismometer in May 1935, the latter was put into operation and records were obtained continuously thereafter.

Meteorological observations including barometric pressure, maximum and minimum temperatures, relative humidity, rainfall, cloudiness, and wind-direction and velocity, were obtained daily at 8 a.m. 75th west meridian time throughout the year. Continuous records were also obtained with barograph, thermograph, hygrograph, anemograph and sunshine-recorder.

Computations and tabulations associated with the magnetic, atmospheric-electric, earth-current and meteorological studies were kept well up-to-date.

The program of manual observations with the ionospheric apparatus, based on a cooperative schedule with the National Bureau of Standards, was continued until March 1, 1935. Interesting and important results obtained were reported upon in papers by Berkner and Wells.

The automatic ionospheric recording-equipment was received in April 1935. In the installation of this equipment it is necessary that it be isolated from sources of electrical interference. The electrical generating equipment, together with the associated batteries and switchboards, was removed from the ionospheric building, leaving this space entirely available for the automatic ionospheric equipment. Because of the unique location of the Observatory on the geomagnetic equator, separate multifrequency recording of each of the two doubly refracted components is possible. This greatly enhances the utility of these records. This procedure is practically impossible of attainment at other locations where the polarization of the components is elliptical. A new antenna-system, capable of high-angle radiation over the entire band, was erected in a north-south plane for recording of one of the doubly refracted rays; this is to be augmented by a similar system placed in an east-west plane for the other component. Thus separate recording of each doubly refracted component on all frequencies may be obtained.

The additional generating equipment, together with requirements for space for the communication-equipment in a location at a distance from the ionospheric equipment, necessitated the erection of a separate power-building (completed in January 1935) to house all generating equipment with batteries and switchboards. A separate room in this building houses the communication-equipment. In addition to the existing 110-volt generating equipment, two 2-kw., 110-volt, direct-current Kohler engine-generators (in use since May 1935), capable of 1.5-kw. output at the Observatory's altitude of 11,000 feet, with provision for a third such unit, were installed in the power-building. In April, also, additional control-switchboards were installed in the power-room to facilitate the inter-connection or interchange of power-units to meet the revised needs of the Observatory. The transfer from 32-volt to 110-volt direct-current for all circuits was nearly completed. Installation of the constant-speed controller is partially completed, a small Leeds and Northrup constant-speed machine meanwhile being in temporary use for partial frequency-control. All new wiring between buildings has been done with shielded wire in underground ducts to minimize local electrical interference.

The first record with the photographically recording ionospheric equipment was obtained May 13, 1935. Weekly summaries are forwarded to Washington reporting on the results while the records and tabulated data are forwarded at the end of each month.

Cosmic-ray observations were temporarily discontinued September 1, 1934, pending the delivery late in 1935 of a precise cosmic-ray meter which is to be one of a world-wide net of stations planned by the Institution's Committee on Coordination of Cosmic-Ray Investigations.

In cooperation with the Peruvian Government and its branches, various data have been supplied. Tabulations are supplied each month to the Servicio Meteorológico Nacional of the meteorological observations at 8 a.m. and of the hourly values of barometric pressure, wind-direction, wind-velocity and sunshine. Meteorological observations are also supplied at frequent intervals to the Engineer of the City of Huancayo. In January 1935 an exhibit was provided for the Quadricentennial Exposition Committee in Lima; this exhibit included photographs of the various laboratories of the Carnegie Institution and of the Observatory and its instruments, reproductions of records, and graphs and diagrams showing the results of research in the various fields of activity of the Department. In May 1935 meteorological instruments were standardized for the Junin Station of the Comisión Agro-nómico. Publications of the Institution relating to the Department's work

in South America were supplied to the Director of the Servicio Meteorológico Nacional.

Dr. Cairns continued as observer-in-charge to September 1, 1934, when O. W. Torreson, who was his first assistant until then, became observer-in-charge. H. W. Wells continued as observer with duties closely associated with the ionospheric investigations. Observer W. E. Scott, with Mrs. Scott and family, arrived September 18, 1934. Observer H. E. Stanton arrived June 28, 1935. T. Astete and A. Macha continued as temporary clerical assistants.

The Observatory has continued to enjoy the helpful friendship of the local residents and of the officials of the Peruvian Government. The American Consulate has given valuable assistance to members of the staff entering Peru. The American Embassy has extended valuable aid in arranging for free entry, generously accorded by the Peruvian Government, of all materials and equipment in the shortest possible time, thus insuring the continuance of the Observatory's program of scientific activity.

COOPERATION WITH OTHER OBSERVATORIES

Apia Observatory, Western Samoa—The cooperative work of the Department in atmospheric electricity and terrestrial magnetism with the Apia Observatory (latitude $13^{\circ} 48'$ south, longitude $171^{\circ} 46'$ west), which began in 1921, was continued. Besides those fields the Observatory does extensive work in seismology and meteorology.

As in former years, the magnetic instruments used were the Tesdorpf magnetometer and the Schulze earth-inductor, the former being employed for measurements of declination and horizontal intensity and the latter for measurements of the dip. In addition to these instruments the Observatory has Eschenhagen variometers which give a continuous photographic record of the declination and the horizontal force and a Godhaven balance which gives continuous records of the vertical force. The scale-value of the horizontal-force variometer was 1.08 gammas per mm. at the base-line, increasing 0.0025 gamma for each mm. of increasing ordinate. The temperature-coefficients of the horizontal-force and vertical-force variometers were 2.3 and 1.7 gammas per degree Centigrade, respectively. The mean values of the magnetic elements during 1934 at Apia are: Declination, $10^{\circ} 42' 2''$ east; horizontal force, 35049 gammas; vertical force (six months only, July to December), -20556 gammas. The Department prepared theodolite-magnetometer C.I.W. No. 9 for use as standard at Apia and standardized it at Washington and at Watheroo. It was in shipment from Watheroo to Apia at the end of the report-year. It will be used while the Tesdorpf magnetometer is being overhauled.

A Benndorf electrometer continued to be used to record values of air potential-gradient at the "Land Station" in the grounds of the Observatory. A redetermination of the reduction-factor to reduce observed values of potential to volts per meter, made October 4, 1934, gave a value of 1.06 which is in fair agreement with the value of 1.00 adopted in the preliminary reduction of the results for previous years. There were 84 zero-days of potential gradient in 1934 and the mean value for these days using a reduction-factor of 1.00 was 117 volts per meter. The twelve monthly values were 97, 120, 114, 131, 112, 121, 128, 118, 119, 115, 121, and 111 volts per meter. The mean hourly values in volts per meter centering on the half hour for 165° west meridian time, beginning with value for interval 0^h-1^h were: 89, 89, 90, 86, 93, 101, 133, 215, 228, 158, 121, 109, 103, 96, 94, 94, 89, 90, 114, 153, 146, 121, 108, and 93.

Toward the end of 1934, the Gerdien apparatus for measuring air-conductivity and the Ebert ion-counter which formed part of the original equipment were so adapted that Wulf electrometers might be used. A Gerdien condenser was supplied by the Department for redetermination of the capacity so that observations with these apparatuses may be expressed in standard units.

In meteorology, as in former years, there were surface observations and measurements of the upper winds using pilot-balloons as well as the preparation of a daily synoptic chart using the observations received by wireless telegraphy at Apia Radio Station from about twenty island stations in the South Pacific. Table 1 gives a climatological summary for 1934. An additional rainfall station was installed at Lotofaga. During July to September 1934, records of meteors were tabulated in cooperation with the Second Byrd Antarctic Expedition.

TABLE 1—*Meteorological summary, Apia Observatory, 1934*

Month	Pressure	Temp.	Rainfall	Rel. hum. (9 a. m.)	Sunshine ^a	Wind- velocity
	<i>inches</i>	<i>°F</i>	<i>inches</i>	<i>per cent</i>	<i>hours</i>	<i>miles/hr.</i>
January.....	29.794	79.4	15.25	80	144.1	5.1
February.....	29.827	79.4	11.54	81	.....	3.6
March.....	29.776	78.6	20.03	84	.....	4.0
April.....	29.824	78.7	7.42	79	.....	3.8
May.....	29.851	79.0	6.09	81	.....	4.9
June.....	29.865	78.7	1.64	78	.....	7.5
July.....	29.859	78.3	7.74	81	.....	6.9
August.....	29.892	78.1	1.10	73	.....	9.4
September.....	29.872	78.7	10.41	77	225.4	7.0
October.....	29.873	78.9	4.90	75	243.6	6.9
November.....	29.806	79.4	14.05	79	188.8	7.7
December.....	29.742	79.4	20.05	81	171.5	6.6
Mean or total.....	29.832	78.88	120.22	79	.....	6.1

^a No readings from February to August account loss of glass ball.

The staff of the Observatory was reduced early in 1934 with the retirement of P. W. Glover; but the original strength was restored in October 1934 by the arrival of W. R. Dyer from New Zealand. The present staff consists of J. Wadsworth (Director), W. R. Dyer, H. B. Sapsford, four clerks recruited locally, and a Chinese assistant.

Tucson Observatory, United States—Registration of air-potentials and of positive and negative air-conductivity, with the necessary control-observations and tests, were continued by Observers-in-Charge A. L. Ludy and J. Wallace Joyce, and their assistants of the United States Coast and Geodetic Survey, cooperating with the Department. As in past years, since initiation of the atmospheric-electric program and for use in that program, we were supplied by the War Department with the complete meteorological data obtained at the Tucson Airport of the Meteorological Service of the United States Signal Corps. The registration of earth-currents, under a cooperative arrangement with the Mountain States Telephone and Telegraph Company, was also continued. The staff at the Observatory made the scalings of all records before forwarding them to Washington.

During the year arrangements were completed for 115-volt alternating-current from the Tucson Gas, Electric Light and Power Company, thus making possible replacing the 32-volt direct-current power-supply for the atmospheric-electric and earth-current instruments by 115-volt current.

Cheltenham Observatory, United States—C.I.W. sine-galvanometer No. 1 was installed at the Cheltenham Observatory during May and June 1935 and is to be used as the Observatory's standard horizontal-intensity instrument beginning in August 1935. Suitable pier-caps were provided by the Observatory to effect constant height for the magnet-systems in the sine-galvanometer and magnetometers being compared. An intercomparison between the sine-galvanometer and the standard magnetometer heretofore used at the Observatory was made. During July 1935 intercomparisons between the sine-galvanometer and the Department's standard magnetometer will be made and hereafter the operations of the Department of Terrestrial Magnetism in maintenance of its extensive comparisons of magnetic instruments and of its provisional International Magnetic Standards will be at Cheltenham.

Arrangements were made by the Observatory to test in its comparison and test building the Department's permivar vertical-intensity variometer. Extensive cooperative experimental work on both old and new instrumental models are being made at the Observatory looking toward improved technique and accuracy.

In January 1935 one of the seven precise cosmic-ray meters constructed for the Institution's Committee on Coordination of Cosmic-Ray Investigations was installed by Dr. R. L. Doan of Professor A. H. Compton's staff, with assistance from Forbush of the Department and from the staff of the Observatory. This is the first of five meters to be established by the Department, in cooperation with other organizations, in accordance with the Committee's desires. The meter, after designs by Bennett and A. H. Compton, gives a continuous record of cosmic-ray intensity and barometric pressure, with suitable time-marks, and with calibrations at periodic intervals. At Cheltenham the meter is mounted in a separate, well-insulated frame structure, the inside room-temperature being electrically controlled so that it may never be lower than 15°5 C. The meter is now in successful operation after overcoming a number of difficulties, among which was a defect in the insulation of the ionization-chamber which required that the bomb be replaced by one from another meter. Early recording was vitiated by the partially ineffective grounding of the collecting system at hourly intervals; however, an appropriate condenser installed between ground and the grounding contact eliminated this defect. Difficulties have also developed in the commutator but these may be eliminated by alteration in its design and in the shape of the brushes. The practical experience gained in the operation of this meter is being utilized effectively in preparing a complete manual of instructions to allow satisfactory uninterrupted operation at the several stations over a period of years.

Little America, Antarctica—With the return of the Second Byrd Antarctic Expedition it is now possible to give the following brief summary of operation of the magnetic observatory at Little America during 1934-35. The *Jacob Ruppert*, flagship of the Expedition, arrived at the Barrier January 17, 1934. Poulter, Bramhall and Zuhn started excavating for the variation-observatory February 4. This was located about 350 feet south by east (true) from the variation-observatory site of the First Byrd Antarctic Expedition, and was constructed according to the plans supplied by the Department except that the roof was made flat. All sides and roof were cov-

ered with blocks of snow. The absolute observatory was constructed in a similar way. It consisted of a single room 8 feet by 10 feet by 7 feet high inside, and was located about 100 feet north of the variation-observatory and connected with it by a tunnel. The pier was sunk to 3 feet below the floor and iced, as was the pier in the variation-observatory.

The la Cour type of insensitive magnetograph began regular recording February 12, 1934, and continued without serious interruption until February 4, 1935. Absolute observations were begun February 27, 1934, and were made weekly until February 2, 1935, except during prolonged periods of disturbance. The azimuth-mark consisted of a Pope lamp which was sunk in the snow at the end of a tunnel 259 feet long and about 6 feet below the surface; bearing was determined by solar and stellar observations.

The range in temperature during the year inside the variation-observatory was not great. During February 1934 the mean temperature remained at about -12°C with almost no daily variation. As the winter advanced there was a slow decrease in room-temperature, but, except during a prolonged cold spell, it never sank below -30°C , while the daily variation was almost zero.

The absolute observatory was heated by means of a "primus" stove placed beneath the open bottom of a copper gasoline-container and from the top of this a flue led out through the top of the tunnel. All steel parts were removed from the primus. This arrangement rendered the room comfortably warm for observing.

The magnetograms lack only a fortnight of completing a full year with inclination at 82° south, horizontal intensity near 0.09 C.G.S. unit, and magnetic declination about $107^{\circ}5'$ east of north. All values exhibit regular fluctuations of various periodicities as well as magnetic storms of considerable magnitude. The preparation of the data for compilation and discussion of the results by the Department was under way by Bramhall as temporary observer and computer from June 10, 1935.

Series of cosmic-ray observations from Panama to New Zealand and thence to the Barrier were made on the *Jacob Ruppert* by Bramhall and Zuhn. Between April 1934 and February 1935, 800 hours of visual observations at fortnightly intervals were made at Little America. Additional data were obtained on a flight of several hours' duration above the camp at an altitude of 11,000 feet.

College, Alaska—Arrangements were made with President Bunnell, of the University of Alaska, to resume the ionospheric studies at College, Alaska. The strategic location of the College Station in the polar region near the maximum of vertical intensity of the terrestrial-magnetic field makes such studies necessary in a world-wide ionospheric survey. This is especially true because of the close relation between disturbances to radio waves propagated in these regions and terrestrial-magnetic disturbances. This work had been under the direction of Professor Fuller but was discontinued in May 1934 because of lack of suitable power-supply. Funds have been made available for the installation of a 2-kw. Kohler engine-generator as an auxiliary power-supply together with a constant-speed controller and rotary-converter, in order that power at a controlled frequency might be available throughout the year. The execution of these plans has been delayed by the untimely and sudden death of Professor Fuller May 30, 1935; with the appointment of Dr. E. H. Bramhall to succeed him as professor of physics at the University, it is hoped this program may be completed and observations resumed in 1936.

REDUCTION OF MAGNETIC DATA

Magnetic data from Watheroo and Huancayo magnetic observatories—The magnetic data from Watheroo for 1933 were completely reduced and the manuscript covering that year has been added to those for 1919 to 1932 which are awaiting publication. Final mean hourly values of the three elements were completed for the Huancayo Magnetic Observatory for 1922 to 1932.

The final annual mean values, based on all days, of the magnetic elements and of the local magnetic constants for the two observatories for the year 1933 and preliminary values for the year 1934 are given in table 2.

TABLE 2—*Annual values of the magnetic elements at the Watheroo and Huancayo magnetic observatories as based upon magnetograms for all days*

Year	Declination <i>D</i>	Inclination <i>I</i>	Intensity-components					Local magnetic constant <i>G</i>
			Horizontal <i>H</i>	Total <i>F</i>	North-south <i>X</i>	East-west <i>Y</i>	Vertical <i>Z</i>	
	° ' "	° ' "	γ	γ	γ	γ	γ	γ
Watheroo Magnetic Observatory								
1933. . . .	3 53.4 W	64 19.8 S	24659	56926	24602	-1673	-51308	35584
1934. . . .	3 47.8	64 20.2	24669	56962	24615	-1633	-51341	35602
Huancayo Magnetic Observatory								
1933. . . .	7 21.4 E	2 04 7 N	29614	29633	29370	3792	1075	29619
1934. . . .	7 18.1	2 08.5	29622	29643	29382	3765	1107	29627

ANALYSIS REDUCTION METHODS AND OBSERVATIONAL PROCEDURE

In the reductions of the magnetic data from the Department's observatories the methods of observation and reduction are constantly subjected to critical examination; improved methods of compilation have resulted. The careful examination of the observational data show also definite goals for necessary or desirable improvements in instruments.

Chance losses of trace—For the years 1933 and 1934 there were chance losses of trace with the Eschenhagen magnetographs at both observatories. In these cases the magnetograms from the rapid-running la Cour magnetograph were scaled to complete the hourly tabulations. In previous years a few losses of record have occurred at both observatories during *severe* magnetic storms. Because of the steadily increasing magnetic activity with increasing solar activity in 1935, it may be desirable that insensitive magnetographs be installed (a) for all three elements at Watheroo and (b) for horizontal and vertical intensity at Huancayo.

Horizontality of vertical-intensity magnet—In reducing the vertical-intensity records from the rapid-running magnetograph at the Huancayo Magnetic Observatory it was noted that at some parts of the day the hourly

values did not agree with those of the vertical-intensity recorded by the Eschenhagen magnetograph. The times of greatest departure were at the times of maxima and minima of horizontal intensity. Appropriate tests showed that the magnet in the Eschenhagen vertical-intensity variometer was out of the horizontal by approximately $3^{\circ}4'$ and hence part of the diurnal variation in horizontal intensity was being recorded on the vertical-intensity trace. Readjustment of the vertical-intensity magnet to horizontal was made. Suitable correction was made for this non-horizontality in the tabulated hourly values of vertical intensity.

Orientation of variometer-magnets—The alignment of magnets in variometers at an observatory should be tested, adjusted if necessary, and reported periodically to insure that the declination-magnet is in the magnetic meridian, the horizontal-intensity magnet is at right-angles to the magnetic meridian, and the vertical-intensity magnet is horizontal. Practical tests may be made readily with an auxiliary magnet as it produces no deflection when its axis is in line with the suspended magnet.

Vertical-intensity base-lines—At Huancayo the vertical-intensity variometer is of the Eschenhagen-Toepfer type in which the magnet is supported by a knife-edge on a plane. Its operation has been attended by many sudden shifts in base-line. In compiling the results, it is often difficult to determine the amount of change. At Huancayo very quiet magnetic conditions in vertical intensity prevail in the first six hours of the day and the daily values of vertical intensity from 3^h to 4^h shows a fairly regular progression. From a knowledge of the scale-value and the difference in scaling of the vertical-intensity trace between that at the hour 3-4 and at the time of absolute observations, it was possible to obtain the absolute value of vertical intensity for the hours 3-4. Sudden shifts in base-line were readily discernible.

Scale-values at observatories—The method of observation and computation of the scale-values for variometer-records of declination, horizontal intensity and vertical-intensity received careful analysis. Since our two observatories began operation, the scale-value of the declination-variometer has been computed from the effective optical lever and the scale-values for the horizontal-intensity and vertical-intensity variometers have been computed from the deflections produced by a small magnet on each of the three variometers in turn; the moment of the small magnet was controlled by the deflection on the declination-variometer. In the computation of all three scale-values, the horizontal intensity at the position occupied by the magnet of the declination-variometer must be corrected for the effect of the magnet in the vertical-intensity variometer. Valid scale-values may also be measured from the deflections produced by passing a known current through a Helmholtz coil properly oriented around the variometers or by the deflections produced by a magnet whose moment is controlled by separate observations.

At the Huancayo Magnetic Observatory during the past two years both Helmholtz coil and magnets have been used for scale-values. In addition to the small magnet, employed since 1922, a large magnet of moment 7500 C.G.S. units is utilized for deflections at a deflection-distance of two meters. Over a period of 13 months the average scale-value at the base-line was 2.12

gammas per mm. with the large magnet and 2.15 gammas per mm. with the small magnet; the difference of one and one-half per cent agrees exactly with the computed effect of the vertical-intensity variometer magnet at the position of the declination-variometer. The scale-values of the Eschenhagen-Toepfer vertical-intensity variometer using both the Helmholtz coil and large magnet showed the average difference between the two methods of only 0.02 gamma per mm. for the sensitivity used of 4.3 gammas per mm. Thus both methods give excellent results. The variometers are not touched during the observation and therefore the possibility of abrupt changes of base-line is lessened. The Helmholtz coil has advantages over the large-magnet method both because the variation-room is not entered and the time consumed in observation is short.

OCEANOGRAPHIC REDUCTIONS

The preparation for publication of oceanographical data secured during the last cruise of the *Carnegie* was continued under the supervision of the Director with the assistance of Ennis, Graham and Hendrix. The assembling and preparation of the numerous necessary graphs and maps showing the vast amount of material collected are rapidly nearing completion.

As noted above, the Department was privileged in making available to the British Admiralty its vast integrated experience on the *Carnegie* for the construction and equipment of the non-magnetic survey-vessel *Research* with which the Admiralty will replace the *Carnegie* for oceanic work. Thus, particularly in connection with design of vessel and of instruments required in oceanic surveys relating to terrestrial magnetism and other geophysical sciences, the value of the Institution's activities at sea will be enlarged.

PHYSICAL AND CHEMICAL RESULTS

The manuscript for the extensive report, and discussion of, the marine bottom-samples prepared by Roger Revelle at the Scripps Institution of Oceanography of the University of California under the direction of Dr. T. Wayland Vaughan was completed. It, with its many illustrations, is now being assembled with other manuscripts for publication.

Graham and Moberg spent a month together at the Scripps Institution in a final revision of the manuscript discussions of the *Carnegie* chemical results to make certain changes necessitated by recent reports in oceanography. In the revised drafts there were incorporated data on oxygen-distribution obtained by the U.S.S. *Bushnell* and U.S.S. *Hannibal* made available by the Scripps Institution.

The tabulations of the oceanographic data of the *Carnegie* supplied before publication to the Deutsche Seewarte were used advantageously by Dr. G. Schott. As a result of his digest of the enormous relevant literature, represented in his book "Geographie des Indischen und Stillen Ozeans" published this year, he has made available for the first time a regional survey of the oceanic waters.

BIOLOGICAL RESULTS

Throughout most of the year, Graham was occupied at the Hopkins Marine Station, Pacific Grove, California, in a continuation of the studies of the

Dinoflagellates of the *Carnegie* plankton-collection. The services of C. A. Dawson were employed for one month to assist in the preparation of drawings for publication. Mrs. N. Bronikovski assisted from March 1935 in the routine examination of the plankton-samples and in the preliminary sketching of organisms. The generous cooperation of the Hopkins Marine Station, particularly of Dr. W. K. Fisher and of Dr. T. Skogsberg, was extended as in previous years.

Good progress was made in the study of the Dinoflagellates of the *Carnegie* plankton-collection. The searching of the samples together with the mounting and sketching of organisms was completed for the Atlantic samples and carried into the southeastern Pacific to Station 48. This phase of the work has now been completed for 275 samples. The number of mounts now totals 1100; the collection of camera-lucida drawings now contains 3103 sketches; the number of species recorded to date is 280.

The final study of the Dinoflagellates is going to be greatly facilitated by the fact that success was attained in liquefying old glycerin-jelly mounts. This will allow the reexamination of specimens in any position, a procedure which has never before been possible in protozoological investigations.

The *Carnegie* material from the southeastern Pacific is particularly interesting when compared with that obtained in the same region by the *Albatross* in 1904-05. Certain differences in distribution are made evident. The distributional records of the *Carnegie* are being correlated with the rather complete hydrographic data which were obtained at each oceanographic station. In spite of the intensive work which the *Albatross* did in certain parts of the southeastern Pacific, the *Carnegie* material is presenting many new records and new species from that area, notably in the genera *Goniaulax*, *Phalacroma*, *Ceratocorys* and *Spiraulax*.

INSTRUMENT-SHOP

As in previous years, the service of the instrument-shop has proved invaluable in every field of activity. The many and varied demands from the Laboratory at Washington and from the two observatories were met admirably in design and construction by C. Huff, in charge, and his staff—Steiner, Lorz, Haase, A. Smith and T. F. Huff.

First in importance of equipment was the continuation of improvement in design of apparatus for study of the ionosphere. This included an automatic photographic-recording receiving-apparatus, partly constructed of new panels and partly of modified panels. One completed receiving-apparatus was constructed and shipped to the Huancayo Magnetic Observatory while two others are under way, one of which is for the Watheroo Magnetic Observatory.

Considerable assistance was given the nuclear-physics program in constructing parts for the high-voltage work. This consisted mainly of the large pump-manifolds for the X-ray tubes and a large number of parts to be used in the construction of a new large X-ray tube.

The conductivity-apparatus for use in stratosphere flights included the standard type of tube and cylinder carried by a specially designed supporting-neck for securing it to the outside of the gondola and a discharge-device,

amplifier, and specially designed recorder on the inside of the gondola. Special problems brought about by the requirements that the equipment operate at low pressure and temperatures required special treatment and experiment to insure successful functioning of the apparatus. The general improvements in design were developed by Gish and mechanical-design details were worked out in the shop.

The Department's sine-galvanometer was installed at the Cheltenham Observatory, and a control-table and constant-temperature cabinet of special design were constructed to be used with it. The temperature in the insulated cabinet is thermostatically controlled within narrow limits. The cabinet contains the standard cells, standard resistances and operating batteries. On the table-top and easy of access to the observer are mounted the control-panel, balancing galvanometer and potentiometer.

A mirror stereoscope for viewing large magneto-stereograms up to 40 by 60 cm. was designed and constructed after a general design by Peters.

An experimental vertical-intensity variometer using permivar elements, designed by McNish, was constructed.

Considerable attention was given to Observatory electrical-equipment details, repairs of instruments, photographic work, safety devices to comply with insurance requirements, pulse-amplifier, relay-racks, repairs to buildings and site, shop repairs and improvements in the shop and miscellaneous items. Other miscellaneous work involved potential-gradient collector sent to India Meteorological Office, cosmic-ray-meter alterations and repairs and shipment of instrument-patterns to the British Admiralty. The much-needed addition of library and filing facilities begun last year was completed.

The annual exhibit required considerable time of the shop-personnel, not only for the Department's contribution, but also in rendering assistance to the other exhibitors.

MISCELLANEOUS ACTIVITIES

Activities in scientific bodies and lectures—Hafstad represented the Department at the London (England) meetings of the International Union of Scientific Radiotelegraphy in September 1934 and of the International Conference on Physics held in October 1934. At the former he presented five communications by Berkner, Fleming and H. W. Wells dealing with our current ionospheric theory and research; he was made a member of the Subcommittee on Ionospheric Measurements and of a Special Committee to outline an international program to be recommended for all stations participating in ionospheric investigations. At the latter he reported on our nuclear-physics researches and made comments on the artificial radio-activity of carbon.

During June 1935 Bartels represented Fleming at a conference in Copenhagen, Denmark, preliminary to the meeting of the Commission of Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization at Warsaw, Poland, to be held in September 1935, to discuss with Secretary la Cour the agenda proposed for that meeting. At the University of Berlin he gave two courses of twelve lectures each during the winter and summer (1934-35) terms on "Erdmagnetismus und Polarlicht"

and on "Physik des Erdkörpers" and in December and January discussed the statistical theory of periodical phenomena in that University's Meteorological Colloquium.

For the Commission on Solar and Terrestrial Relationships of the International Astronomical Union, papers were prepared by Berkner, Fleming and McNish on variations of the upper atmospheric ionization, on researches of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington bearing on solar activity and the Earth's magnetic and electric fields 1932-34, and on solar activity and its relation to terrestrial-magnetic phenomena, respectively.

The Department was represented at meetings of American sections of international and national scientific organizations. At the joint meeting of the American Section of the International Union of Scientific Radiotelegraphy and Institute of Radio Engineers in Washington, April 26, 1935, Berkner delivered a paper on recent ionospheric observations in the Southern Hemisphere prepared by Berkner, Wells and Seaton. Four papers and reports by Berkner, Ennis, Fleming and Rooney were presented at the sixteenth annual meeting (April 1935) of the American Geophysical Union; Fleming and Capello prepared for publication the Transactions of that meeting (two volumes containing 530 pages). Wait represented the Department at the Buffalo meeting of the American Society of Heating and Ventilating Engineers in January 1935, giving a paper on ions in the atmosphere. Gish and Tuve attended the Pittsburgh meeting of the American Association for the Advancement of Science in December 1934 when the former presented an invited paper by Fleming on investigations of the Earth's magnetic field and correlations with solar and atmospheric factors and the latter an invited paper on nuclear reactions produced by high-speed deuterons. At the Minneapolis meeting of the Association in June 1935 Hafstad gave an invited paper on some current nuclear problems in the region below 1000 kilovolts.

At a February meeting of the Washington Section of the American Physical Society, Hafstad discussed recent developments in nuclear chemistry. At meetings of the Philosophical Society of Washington in March and in May, Berkner and Tuve gave talks on the ionosphere observations of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and on some recent developments in high-energy physics.

Exhibits—The Department's contribution to the Institution's annual exhibit presented advances in our knowledge of the diurnal variations of the Earth's magnetism derived from the observation and interpretation of the magnetic changes occurring at the Institution's observatory at Huancayo, Peru. Observed average daily changes in compass-direction at Watheroo, Huancayo, and other observatories were represented by movements of "needles" mounted on a large map of the world at the locations of the various observatories. Light and shade, passing across the map, gave the effect of the movement of the circle of illumination around the Earth while the needles performed their synchronized motions. The second phase of the exhibit showed the manner in which the observed compass-changes are caused. A 30-inch sphere represented the Earth about which a system of wires slowly rotated, duplicating the electric currents flowing in the ionosphere. Small compass- and dipping-needles mounted at various points

on the sphere were influenced by the currents in the wires and reproduced by electromagnetic means the observed movements of the compass-needles, mechanically controlled on the map. The final stage of the exhibit translated the working models into graphical terms and showed the current-system necessary to produce the average magnetic variations, its modification required by the large magnetic variations at Huancayo, and an explanation of how the extraordinarily strong electric currents in the Western Hemisphere are produced.

An exhibit illustrating by placard the nuclear-physics investigations of the Department was prepared for the December 1934 meeting of the American Association for the Advancement of Science at Pittsburgh.

Exhibit material was also prepared for use October 10, 1934, at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey at the exercises celebrating the completion of one-third century of continuous operation of that Observatory, and Fleming and Bartels gave short addresses.

Public progress-reports—Cooperating with the Institution's Advisory Committee on Public Progress-Reports, material for eleven clip-sheets and two news-service bulletins based upon work of the Department were prepared by McNish. Subjects supplied for the clip-sheets were: Condensation-nuclei in the human breath; earthquake-recording in the Andes, anthropomorphic connection between Easter Island and America; radio exploration of the ionosphere; the Sun's rotation and the Earth's magnetism; a non-magnetic ship; variation of atmospheric ionization; electric currents in the Earth's crust; electric conditions of the high atmosphere; air-conductivity measurements in the stratosphere; and ionization of the Earth's upper atmosphere. Lengthier articles with illustrations on the Earth's magnetic field and correlations with solar and atmospheric factors and on the daily changes in compass-direction were supplied as bases for news-service bulletins. From time to time advice and cooperation have been given various newspaper and magazine writers in the preparation of special articles on scientific work.

Staff meetings and colloquia—Sixteen afternoon biweekly staff meetings were held during October 1934 to June 1935. The subjects covered were: Random fluctuations, persistence, and quasi-persistence in geophysical and cosmical periodicities (Bartels); the Canadian Polar-Year Expedition (Davies); comparison of measured air-ionization with that computed from observed ionic contents (Wait); the generation of electric charge by disrupting water-drops (Gish); the current-system in the ionosphere for the Western Hemisphere (McNish); the new precision cosmic-ray meter and some recent results (Doan); recent developments in ionospheric research (Berkner); thunderstorm electricity (Gunn, two meetings); nuclear transmutations and the basic structure of matter (Hafstad); magnetism and the atomic nucleus (Gamow); the intermediate ions of the atmosphere (Wait); effect of eccentricity of magnet during magnetometer deflections and scale-value determinations by Helmholtz coil (Johnston); the instrument-maker's point of view regarding the design of scientific apparatus and demonstration of shop-equipment (Huff); recent developments of magnetic instruments resulting from cooperation of United States Coast and Geodetic Survey and

Department of Terrestrial Magnetism including review of program and tests of new ideas (McComb), the theory of the sine-galvanometer (Forbush), and measurement of absolute current in connection with sine-galvanometer observations (Johnson); development of electrical apparatus for magnetic measurements (Johnson) and comparison of Adie, Eschenhagen, la Cour, and Askania variometers (Hartnell).

Members of staff attended many of the weekly morning staff meetings of the National Bureau of Standards. At one in February, McNish spoke on terrestrial magnetism and the upper atmosphere, and, at another in May, Gish spoke on the major problems in atmospheric electricity.

The atomic-physics colloquium continued its weekly evening meetings at the National Bureau of Standards and at George Washington University. With the appointment of Dr. George Gamow as professor of theoretical physics, arrangements were made by the University to look after the administrative details concerned with this colloquium. During October and November 1934 the evening statistics colloquium had a number of meetings at the Department, Bartels, Forbush and McNish discussing questions of analyzing periodic phenomena.

Conferences—Hafstad took part in a conference of super-voltage, X-ray physicists in Minneapolis June 20, 1935. The stimulating Conference on Theoretical Physics held during April 1935 and conferences on ionospheric studies at Washington in April and at Deal, New Jersey, in June 1935 are referred to above. Berkner represented the Institution at a conference for discussion of cooperation between non-profit organizations and radio broadcasters in the field of education held under the direction of the Federal Communications Commission on May 15 and 16, 1935. Fleming, Davies and Ennis held several conferences with Messrs. C. J. McGregor and A. R. Stickley of the United States Weather Bureau to consider and advise that Bureau on method of preparing for publication manuscript and discussion of the auroral data obtained at Point Barrow and elsewhere in the United States during the International Polar Year of 1932-33.

Continuing as a member of the special Committee for Coordination of Cosmic-Ray Investigations appointed by President Merriam, Fleming took part in several meetings of the Committee and in conferences with Professor A. H. Compton, Dr. Richard L. Doan, Dr. Thomas H. Johnson, and Wright and Forbush regarding the plans for installations of the precision cosmic-ray meters which were completed and tested. Arrangements were made by the Department for the installation of one at the Cheltenham Magnetic Observatory in January 1935 and for a second one to be placed at the Huancayo Magnetic Observatory and which was shipped in August 1935. (For details of the Committee's work during the year, see pages 314 to 328 of Year Book No. 34.)

Library—As in previous years, the library acquired through purchase or exchange practically all new publications on terrestrial magnetism and electricity and allied subjects including standard works on physics and mathematics. Although unfavorable exchange rates and high prices in the case of some foreign countries still persist, the Department obtained practically all foreign books published during the year relating to its activities. During the report-year 665 books and pamphlets were accessioned, making total

accessions now 22,869. Among these are 16 volumes of standard works dealing with mathematics and astronomy donated by W. J. Peters. The practise was continued of carding, classifying and filing in the library-indexes all important articles on terrestrial magnetism and electricity as well as other subjects of possible interest to the Department appearing in current scientific periodicals of which about 100 are regularly received.

Librarian Harradon continued active part as associate editor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity* and edited contributions in foreign languages and those in English written by foreign authors. He also translated and abstracted some foreign material for publication in English. Abstracts and notes on current progress were prepared as well as the annotated bibliography of recent publications published in the *Journal*.

Articles, documents and letters—some at the request of the Institution—were translated from foreign languages, in particular those pertaining to international scientific bodies and meetings. Cooperating with Science Service, news items regarding Department activities were prepared for publication in the *Journal of the Washington Academy of Sciences*.

The published list of contributions for the year 1934 by members of the staff, compiled by Harradon, shows that these totalled over 1400 on December 31, 1934. The distribution of reprints in foreign countries was done through the facilities of the International Exchange of the Smithsonian Institution, thereby economizing time and expense.

The library was used extensively by students and research workers from various institutions. Inter-library loans were made to libraries in and outside of Washington. The cordial reciprocal relations with other libraries, particularly the Library of Congress, were maintained.

Since September 1934, in the absence of Kolar because of protracted illness, Dove was in charge of the files. He took increasing part in the care and distribution of the departmental reprints and prepared for the binder the "Contributions from the Department of Terrestrial Magnetism during 1934."

Office administration—The large volume of correspondence and accounting work concerned in the maintenance of regular activities at Washington and at the two observatories and the growing amount of editorial work in preparation of manuscripts as many investigations approach completion have taxed the small clerical staff. Without the initiative, constructive suggestions, and application of Chief Clerk M. B. Smith and Property Clerk Capello much of the year's work would have been seriously handicapped. To them and to the thoroughness and accuracy of their assistants Moats, Hendrix and Dove must be credited the success of an essential share in the Department's progress during the report-year.

Bibliography—A list of the published contributions of investigators and research associates is given in the Bibliography of the Institution as reported by the Division of Publications.

ANTHROPOLOGY

Aberle, Sophie D., United Pueblos Agency, Albuquerque, New Mexico.
Study of the growth and development of Indian children.

This program has been carried on during the past three years with aid from the Carnegie Corporation of New York and with the cooperation of Dr. Madison Bentley, of Cornell University. During the past year other studies have been added in cooperation with the research program of the Carnegie Institution of Washington and the activities of the U. S. Office of Indian Affairs. Dr. Aberle is at present serving as General Superintendent of the United Pueblos Agency of the Field Service of this Government office, and her studies under the auspices of the Institution are being carried forward with the assistance of Miss Elizabeth H. Pitney.

A brief outline of various investigations follows.

GROUPS STUDIED

The study has focused on the selected group of 200 Indian children, now 9 to 13 years old and living in 6 Rio Grande Pueblos and 2 Hopi villages, which has been under observation for three years. To obtain a more strictly comparable group of White children, 50 Spanish-speaking children from Chamita have been included in the past year. These children, of the same ages as the Indian children, have been selected from a population which, from a study of local records, is judged to be stable and homogeneous and which lives under economic and environmental conditions similar to those of the Indian children studied. A number of supplementary groups have been used for additional special studies.

PHYSICAL MEASUREMENTS

To obtain a broad background for more detailed physical and anthropometric studies and a general picture of physical size, body-proportion and yearly increments of growth, the height, sitting height, and weight of all the Pueblo and Hopi day-school children, 1500 in number and 6 to 16 years old, have been taken for three successive years and the bicristal diameter for one year. The absolute and relative measurements are now being analyzed by the statistician of the Children's Bureau.

The detailed anthropometric study has been continued with a third annual series of more than 50 measurements on the group of 200 Indian children and a first series on the 50 Spanish children. The Spanish group affords direct comparison with the Indian group, not only of body-growth and face and head characters but also of the physical changes significant of puberty.

A special study has been made of the growth of the mammary gland. Size of the breast has been correlated with the age, height and weight of all the Pueblo and Hopi day-school girls over a period of three years. In the selected group of 250 Indian and Spanish children the two diameters of the nipple have been taken in addition to the size of the female breast.

SKELETAL

A second series of X-ray pictures of the 200 Indian and a first series of the 50 Spanish children have been made. As in the preceding year, both anterior-posterior and lateral views of hand, wrist, foot, ankle, elbow and knee were taken.

MEDICAL

A thorough physical examination of the 200 Indian children was made by Dr. Ethel Dunham of Yale University and the Children's Bureau. The examination included not only clinical findings, but also blood and urine analyses, X-rays of abdomen and chest, Mantoux and Wassermann tests. This is the first complete physical examination ever given to Indian children. Dr. Dunham is now ready to publish a report on the health of Pueblo Indian children.

X-rays of abdomen and chest, blood counts, and Wassermann tests were taken on the group of 50 Spanish children. The shape of the thorax of the Indian child is being compared with that of the White and the supposition among Indian Service doctors that the pathology of the Indian chest differs markedly from that of the White is being checked.

A special study of the effect of an excess of vitamin A upon trachoma was made. Of 16 children at Fort Apache having definite trachoma, 8 were given more than adequate amounts of halibut liver oil. It was found to have no effect upon either the progress or the cure of the disease.

A record has been kept for the last two years of all major diseases, operations and injuries of the 200 Indian children.

DENTAL

A complete dental examination was given the 200 Indian children by Dr. Sumter Arnim of Yale University. Observations were made on the development of the dentition, the number and location of caries and the condition of mouth and gums. One of the most interesting findings was that of white spots in the enamel of the teeth of most of the children. As one of the first approaches to the solution of the problem of whether the enamel defects are true mottled enamel caused by fluorine in the drinking water or whether they are due to a nutritional deficiency, samples of water from all the wells from which the children drink have been analyzed for fluorine by Dr. H. V. Smith, University of Arizona.

NUTRITIONAL

Fifteen sample noonday and evening meals were collected from as many homes at San Juan and were sent to Dr. Francis G. Benedict, Director of the Nutrition Laboratory of the Carnegie Institution, for a quantitative determination of calories and food constituents.

Since a study of the foods eaten from day to day in three pueblos had shown the typical pueblo diet to be deficient in vitamin A, a more than adequate amount of A in the form of halibut liver oil was added to the diet of one half of the group of 200 Indian children, the other half being kept as controls. The halibut liver oil has been given to the children on each school day for the second successive year.

DISTINGUISHING TRAITS

Foot and palm prints of the 200 Indian children, 200 Spanish children (including the selected group of 50) and of 100 Navajos have been made. The patterns of the plantar and palmar lines are now being analyzed by Dr. Harold Cummins, Tulane University.

Hair samples have been obtained from the same 200 Indian and 200 Spanish children and have been sent to Dr. C. H. Danforth, Stanford University, for histological study.

The skin color of the 200 Indian and 50 Spanish children was recorded by the color-top method.

The blood grouping of the 200 Indian and 50 Spanish children has been determined. The typing was done by Dr. Fred Allen, University of New Mexico.

Progress has been made in developing an eye-color standard, but current methods have been found unsatisfactory.

PSYCHOLOGICAL

Simple psychological problems, which involved perceiving, remembering, imagining, comprehending, and so on, were devised with a group of 40 boys and girls in the Albuquerque Indian School, and later given, in final form, to 100 of the group of selected Indian children.

In order to make comparisons with White children, the same problems were given to 100 public-school, native-born, White children in Ithaca, New York, and to 100 Spanish children in Chamita.

The psychological examinations have been given under the direction of Dr. Madison Bentley. Miss S. G. Longwell, of Cornell University, has carried them out with Ithaca and Chamita groups, using methods comparable with those for the Indians.

HISTORICAL

The records of San Juan parish for the period 1726-1934, comprising birth, death and marriage registers and a parish census, have been abstracted. 14,000 births, 6000 deaths and 2500 marriages of San Juan Pueblo and 12 Spanish communities have been copied with notations on parentage, intermarriage, remarriage, multiple births, adoptions, illegitimacy, and social and civil status.

The records have been made available through the kindness of His Excellency, the Archbishop of Santa Fe. Assistance in the task of translating and abstracting has been given by F.E.R.A.

A beginning has been made in arranging the material in such form that a study of population and in vital statistics may be made and that the genealogies of the San Juan Indian children in the selected group and of the 50 Spanish children may be traced.

A bibliography of physical, medical and ethnological studies of the Southwest has been completed by a trained bibliographer whose services were loaned by the Children's Bureau.

Seventy-eight items have been collected as a nucleus for an historical and ethnological library of the Southwest.

Reeves, Ruth, New York City, New York. *Study of Art Motifs in Middle America.*

Under sponsorship of the Carnegie Institution of Washington and with aid of a grant to the Institution from the Carnegie Corporation of New York, Miss Reeves visited Guatemala in the spring of 1934 where she spent four months traveling through the highlands and making collection of native Indian textiles. During the past winter these fabrics have been exhibited in New York City under the auspices of The National Alliance of Art and Industry, and are now being routed to various art museums, universities and schools in the United States. Through such exhibition, which has been supplemented by a collection of costumes typical of various village communities of the highland people, made by Edith Ricketson of the Institution's staff, Miss Reeves has hoped to show to the people of the United States something of the mood and color of the life of the Indians of Guatemala.

Through such an opportunity to see these Maya textiles which are being woven and worn by these friendly tribes today, the Institution hoped that another step would be taken in proving to the public that the Americas had a cultural past which compares favorably in many respects with the first great civilized societies that developed in the ancient Near East. It was also thought possible that through opportunity to examine this rich Guatemalan handicraft, our own textile designers and manufacturers might receive the same sort of inspiration which has come from similar exhibitions of Mexican, North American Indian, African or Scandinavian folk art.

To point the way to a more intelligent use of this material, the exhibition also includes a group of Miss Reeves' own hand-blocked and hand-loomed textile designs, as well as a machine-produced group of Miss Reeves' adapted designs as developed under commercial auspices.

In developing modern designs from their source inspiration in the native specimen, Miss Reeves has been more influenced by present-day trends and needs in a highly industrialized community than by the simpler conditions which produced the original Guatemalan textiles. She considers that these Indian colors and textures and designs are so valid in terms of their traditions and their present life that if Twentieth Century designers copied them slavishly the result would be a sterile and uncreative performance.

Based upon Miss Reeves' interesting field studies and subsequent use of textile materials, the Institution has issued a News Service Bulletin entitled "Textile Arts of the Guatemalan Natives."

ASTRONOMY

Albrecht, Sebastian, Dudley Observatory, Albany, New York. *Studies of radial velocities.* (For previous report see Year Book Nos. 31, 32.)

Alpha Cygni, of spectrum class A2p, has been under investigation. The spectrum is very difficult for both measurement and interpretation. Nine of the new series of three-prism spectrograms taken at the Yerkes Observatory were kindly placed at the disposal of the writer by Director Struve. Wave-lengths, intensities and widths have been determined for all measurable lines from $\lambda 4250$ to beyond $\lambda 4700$.

In addition to a strong and very broad $H\gamma$ and a strong ionized magnesium line at $\lambda 4481$, these spectrograms show many strong lines, due principally to the ionized gases of iron, titanium and chromium. Of the neutral lines, those due to iron are by far the most numerous. However, as in the case of γ Geminorum, which had been suspected of having a background of faint lines by Dr. Keivin Burns as well as by the writer, the α Cygni spectrum likewise seems to have many faint lines which are close to the limit of visibility. A careful examination of a good plate on the spectrocomparator leaves a persistent impression of reality of the faint lines. These lines are so faint that the considerable range, from plate to plate, in effective intensity of exposure, contrast and fortuitous arrangement of silver grains readily causes them to be not measurable or to fade out entirely. Consequently it has been possible to secure only one or two measures for many of the suspected lines. Under the circumstances, a small number of these measures will undoubtedly refer to spurious lines. However, the evidence now available proves that the background of faint lines is unquestionably real. The definite confirmation of these weak lines is brought out strikingly when a line-for-line comparison is made between the tables of observed wave-lengths for α Cygni and γ Geminorum. Even though results for γ Geminorum are based on only three spectrograms having a considerable range in plate density, the agreement of the observed wave-lengths with those for α Cygni is remarkably close, as for example the value $\lambda 4565.168$ in α Cygni and $\lambda 4565.128$ in γ Geminorum. Many of the faint lines which were measured in these two stars are also present in the spectrum of α Canis Minoris, which is of the later spectrum class F8. The definite confirmation of this background of faint lines proves that the spectra of these two class A stars are not as simple as had formerly been supposed.

The radial velocities obtained from the nine plates of α Cygni vary from $+0.9$ km./sec. to -6.0 km./sec. This star is known to have a variable radial velocity, of apparently non-periodic nature. The mean of -2.8 km./sec. is in close agreement with the mean value of -3.1 km./sec. which was obtained recently by Dr. G. F. Paddock at the Lick Observatory from 794 plates.

Relative displacements in wave-length between certain groups of lines were found. However, no general relation like "ionized minus neutral" adequately expresses these displacements. Thus, twenty-two normal lines of ionized titanium show a shortening in wave-length of 0.022 angstrom unit relative to seventeen normal lines of ionized iron, while thirty-eight lines of neutral

iron have only a very slight displacement relative to the lines of ionized iron. Moreover, line intensity plays only a minor part, if any, in the relative displacements.

An interesting by-product of this investigation is the discovery that each of the nine spectrograms of α Cygni, of the newer series of plates, gives progressively greater plus radial velocities toward longer wave-lengths. This is opposite in sign from the original effect derived for the older series of plates. It was supposed that this earlier effect, attributed to a secondary coma of the camera lens, had been eliminated by re-figuring the lens. Apparently it is still necessary to determine and apply corrections for effects which are progressive with wave-length.

BIOLOGY

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-33.)

Since genes borne in chromosomes are known to be the active agents in all forms of mendelian inheritance, it is desirable that we acquire as complete knowledge as possible of the occurrence and distribution of genes in those species of animals and plants most useful to man. To this end our studies of the laboratory rodents have long been directed. Knowledge of the genes of rabbits, rats and mice is more complete than our knowledge of the genetics of any other mammals, including man. We are seeking to extend this knowledge in all possible directions.

In the rabbit colony, investigation has been continued of the linked genes, brown coat, yellow fat and albinism, with a view of determining more accurately the crossover percentages and the amount of interference. A more precise quantitative determination is also being made of the linkage between two genes for short (rex) coat, r_1 and r_2 , by means of backcross matings. Incorporation of all three known rex genes in a single race has not yet been accomplished, possibly because of inferior vitality on the part of animals homozygous for all. The nearest approach yet made to this objective is the production of a vigorous male homozygous for r_1 and r_2 (the linked genes) but heterozygous for r_3 .

New rabbit mutations taken under investigation the past year include: (1) "*satin*," a change in the character of the hair which diminishes the hair diameter, makes the medulla solid instead of vacuolated, and the hair surface very smooth, so that the hair colors are more brilliant. This is a recessive character.

(2) "*Hydrophthalmus*," a malady similar to glaucoma in the human eye, in which the eye becomes distended with fluid and may later become blind. This is an apparent recessive but with normal overlaps; i.e. affected individuals produce some normal offspring as well as affected ones, both classes, however, probably transmitting the mutant gene.

(3) and (4) *Dwarf and brachydactyly*, recessive characters discovered at The Rockefeller Institute and described in "*Science*" by Doctors Green, Brown, *et al.* Stocks of these animals have been supplied to us through the kindness of Dr. Wade Brown, in order that we may investigate their linkage relationships, a study which the discoverers were unable to undertake.

A renewed study of the inheritance of lop (long) ears in rabbits, made in cooperation with Dr. S. C. Reed, now in its third experimental generation, is nearing completion.

Dr. P. B. Sawin continues to maintain his rabbit colony in part at Providence and in part at The Bussey Institution. He is studying the genetics of variations in the number of vertebræ and ribs in the rabbit's skeleton, and in association with Dr. Stewart of Brown University, of differences in serological reactions to human blood.

A study of blood groups in the Norway rat is being made by Mr. Sumner Burhoe. During the academic year his animals are kept at The University

of Maryland; in the summer they are kept at The Bussey Institution, where cooperation with the staff of the State Antitoxin Laboratory proves very helpful.

In cooperation with Dr. Helen Dean King, of the Wistar Institute, I am making a study of the linkage relations of all known genes of the rat. Thus far one new linkage has been discovered between the mutant genes curly coat and cinnamon (brown). The linkage is a loose one with about 40 per cent crossing-over. Previously known for the rat was a single linkage group for the three genes, albinism, red-eyed yellow and pink-eyed yellow, which was studied some years ago by my assistants, Wright, Dunn, Wachter, and myself, as noted in earlier reports.

The house-mouse remains the premier mammal in number of known mutant genes and linkage systems. It is being studied intensively by my colleagues, Dr. C. E. Keeler, Dr. S. C. Reed and Mr. L. W. Law, as well as by myself. Dr. Keeler has described two new recessive mutations discovered by him in inbred families of mice, (1) "waved₂," a character resembling the rex mutations of rabbits, and (2) "headdot," a new type of white spotting. The linkage relations of these are being investigated in the case of waved₂ by Mr. Law; in the case of headdot by Dr. Keeler himself.

A linkage study of waved₁ (the mutant described by Crew) has been made by Mr. Burhoe with results thus far negative. It is independent of 14 other mutant genes, all of which are mutually independent. It thus becomes a marker for a fifteenth chromosome. The time is approaching when all 20 chromosomes of the mouse will carry identifying genes, a situation as yet realized in no mammal and in no animal other than *Drosophila*. When this is attained, mammalian genetics will be on a firm experimental basis.

Dr. Reed has completed a study of harelip in mice, a character similar in its heredity, as in its morphology, to harelip in man. A single recessive mutant gene is necessary to the development of harelip but is inadequate to cause its formation except against an appropriate background of agencies both genetic and environmental. It is believed that much heredity is of this nature, particularly in the case of functional characters such as mental traits.

For the past two years, in cooperation with Dr. W. H. Gates of Louisiana State University, Dr. Reed and I have been studying size inheritance in a mouse cross similar to, but not identical with, the one on which Dr. C. V. Green has based the conclusion that a gene or genes making for increased body-size is inherited in the chromosome bearing the brown coat gene. We have made a cross between the Japanese waltzing mouse (males of which weigh, on the average, 17.6 grams) and a race of the house-mouse having pink-eyes, short-ears, and a dilute brown coat (and weighing, in the case of males, about 26.2 grams). The F₁ hybrids, which are remarkably vigorous animals, are of a uniform black color and weigh about 25.4 grams in the male sex. A backcross of F₁ males to dark-eyed dilute brown females (of the race studied by Green) yields animals of four color classes in equal frequencies, viz. (1) intense black, (2) dilute black (blue), (3) intense brown, and (4) dilute brown. Average weights, at six months of age, for a population of 563 males are (1) blacks, 28.24 ± 0.16 grams; (2) blues, 28.64 ± 0.17

grams; (3) browns, 29.09 ± 0.18 grams; and (4) dilute browns, 30.01 ± 0.17 grams. Brown mice are 2.04 per cent heavier than black mice, the difference being 7 times its probable error. Also, dilute mice are 0.67 per cent heavier than intense ones, the difference being 4 times its probable error. In body-length, at 6 months, similar differences are found between blacks and browns, and between intense and dilute mice, but of still greater statistical significance. The difference between blacks and browns, 1.96 mm., is 11.5 times its probable error, 0.17. The difference between intense and dilute males is 0.95 mm., which is 5.5 times its probable error, 0.17.

Green is thus shown to have been right in his original conclusion that both the brown chromosome and the dilution chromosome furnished by the house-mouse parent carried an influence making for larger body size. But it appears that the explanation which he adopted was less fortunate, *viz.* that the added size was due to a specific gene or genes influencing size which were linked with the brown and the dilution genes, respectively. We find, on the basis of a backcross now being made, that the increased size is probably due to the physiological action of the brown gene and the dilution genes themselves.

Nevertheless, we find such minor influences on size as these mutant genes exercise to be a wholly inadequate basis for an explanation of the large differences in body size which exist between the parent species of mice, or the still larger differences found between different breeds of the domestic rabbit. The problem of size inheritance accordingly merits further study, and this we propose to give it in a variety of mouse crosses now in progress.

Conger, Paul, Washington, District of Columbia. *Continuation of investigations of Dr. Albert Mann, and preparation for publication of results of studies on Diatomaceæ.* (For previous reports see Year Books Nos. 18-33.)

Activities during the past year centered chiefly around a continuation of studies on collections made in Chesapeake Bay and in the vicinity of Cape Cod. In addition to the various purely scientific aspects of these studies, interest in them is enhanced by the probable fact that the extensive fisheries in these two important fishing areas are of such a type as to be directly and closely dependent upon the richness of the local diatom floras, and subject to any factors which influence from time to time the abundance of these floras.

Eight weeks during the summer of 1934 were spent at the Chesapeake Biological Laboratory, collecting in the general area of Chesapeake Bay and carrying on investigations on diatoms. For six weeks of this time a course on diatoms was given to five graduate students, this being its second summer. The students cooperated in collecting, and the course was otherwise fruitful of information as to the relative importance of various phases of the subject and methods of presenting them. A lecture was given as part of the general evening series at the laboratory on the subject "Some Fundamentals of Diatom Biology and their Significance."

As usual, a considerable number of requests was answered during the course of the year for information on the general subject of diatoms, and

samples of material were sent in response to specific requests. Some foreign exchanges of material were made.

Cooperation was given engineers of the Johns Manville Company and the Division of Engineering of the U. S. National Museum in the assembling and installation of an exhibit portraying the methods of mining, and the representative commercial uses of diatomaceous earth, in the Arts and Industries Building of the National Museum. Within the knowledge of the writer, this is the first exhibit of its kind to have been placed in any museum, and in view of the rapidly increasing applications of the material and the great expansion of the industry, it proves to be an exhibit of growing popular interest.

A rather detailed progress report and general statement of the accomplishments, status and program of activities of our laboratory since its inception in 1919 was prepared for the general information of the officers of the Institution.

Work at our laboratory was considerably inconvenienced and somewhat retarded for over two months in the winter and spring, due to much needed and extensive repairs and renovation of the quarters, in conjunction with a general program for such work throughout the building. Much obsolete material was disposed of and greatly improved facilities for the storage of the collection were obtained. Opportunity presented during the work of moving the collection, for observation of the extent of deterioration of the stored materials over a period of several years past, and it was found to be rather worse than suspected, indicating that a considerable amount of time and labor would be necessary for its proper restoration.

In February, at the request of one of the large silk companies in Pennsylvania, over one-hundred photographs of diatoms, selected for their clearness, uniqueness and diversity of design, were furnished this company to be used by their artists in the preparation of designs for the printing of silks. Shortly thereafter, however, a decided slump in the textile industry prevented the continued progress of this plan, though it is hoped that it may be resumed in the near future.

A talk on the biology of the diatoms and their relation to aquiculture was given before the class in Aquiculture of the University of Maryland. This most important phase of the significance of the diatoms is receiving increased attention, in which the University of Maryland is taking a very progressive part.

Some new methods for preparation and mounting of diatoms were evolved, whereby their storage and handling are greatly facilitated, and the optical qualities of their observation are increased.

Meetings attended during the year included the Conference of the Division of Animal Biology of the Carnegie Institution and the Maryland Biology Teachers Convention, both at Baltimore; the American Shell Fisheries Association, the American Association of Museums, and the American Geophysical Union, Section of Oceanography, the three latter meeting in Washington.

A brief list and discussion of the diatoms by the writer was included in a paper entitled "The Microflora of the Mud Deposits of Lake Mendota," published by Dr. Fred T. Williams and Dr. Elizabeth McCoy in the *Journal of*

Sedimentary Petrology for April of this year. This paper was prepared in association with other studies on the bacteriology of these deposits, the latter being the main purpose of the investigations.

Certain conditions prevailing during a short period in the autumn in the upper waters of the Potomac River proved particularly favorable for the growth of a very minute diatom, *Synedra acus* Ktz. As a result there occurred a sudden increase of this diatom in almost unbelievable numbers in the river waters serving as local water supply for Washington and vicinity. This outburst created a serious situation at one of the city's large filtration plants by the stoppage of their filters. The cost of chemicals for control, and the subsequent washing of the filters, was, in excess of normal, over seventeen hundred dollars. This situation, though the worst in many years, is a more or less frequently recurrent condition and is an instance of the potency of so small an organism. In this connection assistance was given in the identification of the offending organism, and factors influencing its growth and control were discussed with the bacteriologist and chemists of the filtration plant.

Work on the collections of the *Carnegie* was necessarily suspended during the year, owing to the serious illness of Dr. Mann. It is expected that this work will be resumed next year with the hope of completing his manuscript.

The final illness, and death on February first, of Dr. Albert Mann, took from our laboratory the inspiring leadership and enthusiastic personality of its founder and organizer. The keen insight of Dr. Mann into the importance of diatoms and problems relating to them, together with his profound knowledge of the subject, had made him for many years a preeminent authority in this field, and a stimulator of much that has been done in diatom research in this country, as well as abroad. He pointed out the usefulness of, and need for, concentrated and continued research upon various phases of the subject, which led to the recognition of its importance and of the value of Dr. Mann's accumulated knowledge by the Carnegie Institution, and the initiation and support by them of the first official laboratory devoted solely to such study under the directorship of Dr. Mann. Dr. Mann's death is a great loss both to the work here and to this phase of science in general. The vast collection built up by him in more than fifty years of industrious and discriminating work, and a considerable number of extensive publications in this field, remain as a lasting memorial to him and a continuing influence of his work, his ideas, and his opinions.

Dice, Lee R., University of Michigan. *Studies of the ecology and genetics of North American mammals*. (For previous reports see Year Books Nos. 31-33).

The studies of variability in *Peromyscus* which have been in progress for the past twelve years at the University of Michigan have been continued, and during the past year 43 stocks of the subspecies *albifrons*, *artemisiae*, *bairdii*, *gossypinus*, *gracilis*, *leucocephalus*, *nebrascensis*, *osgoodi* and *polionotus* have been added to the breeding colony. These stocks came from the states of Florida, Idaho, Michigan, Montana, Nebraska, North Dakota, South Dakota and Wyoming. For variability studies 1634 specimens were prepared during the year. Measurements and statistical computations have been com-

pleted for a report on variability in *Peromyscus leucopus*. Considerable progress was made on the computation of data for studies of variability in the species *californicus*, *eremicus*, *truei* and *boylii*. The variability of none of these species has previously been studied. The measurements and statistical computations of the variability of a large number of additional stocks of *Peromyscus maniculatus* have been nearly completed.

The *Peromyscus* colony was moved during the year from the Museum of Zoology, University of Michigan, to much larger laboratory space in the building of the Laboratory of Vertebrate Genetics and the colony has been considerably enlarged.

A report on the inheritance of subspecific characters in *Peromyscus maniculatus* has been completed for publication. In this study it is shown that body dimensions and pelage color in crosses between *Peromyscus maniculatus rufinus* and *Peromyscus maniculatus sonoriensis* are inherited in general in a blending fashion. There is very little indication of segregation in F_2 . The F_2 hybrids are not more variable in these characters than the F_1 generation. There seems a tendency for the F_1 hybrids, as shown by reciprocal crosses, to resemble their mothers in certain characters and their fathers in other characters. These results are not consistent with the theory of multiple factors without dominance. However, the data are insufficient for a critical test of that theory. A large number of additional subspecies crosses have been begun by Dr. Frank H. Clark and it is proposed to make an intensive study of the mode of inheritance of subspecific characters in these mice. Preliminary data on a cross between *Peromyscus m. bairdii* and *P. m. nebrascensis* indicate a segregation in the F_2 of at least part of the color differences between the two parent subspecies.

Certain of the stocks of *Peromyscus maniculatus nebrascensis* taken in the Sand Hills Region of Nebraska show a considerable amount of variability in coat color. Dr. Frank H. Clark has established a number of selection lines in these stocks in order to secure information on the amount of genetic variability in wild populations.

A first report on the mode of inheritance of waltzing and epilepsy in *Peromyscus* has been completed. It is shown that both of these characters are wide-spread in *Peromyscus*, occurring in numerous localities in different subspecies and species. Two types of waltzing are indicated to be due to different genes. In one stock waltzing and epilepsy are combined, but it is not certain that two genetic factors are involved. The study is being continued by Margaret L. Liebe. The shaking of a bunch of keys has been found to be the most successful stimulus to the production of the waltzing movements and epileptic seizures. In order to secure a uniform stimulus a mechanical key shaker has been developed.

The oestrous cycle of *Peromyscus maniculatus* has been studied by Dr. F. H. Clark by means of vaginal smears. The oestrous cycle in this species, during the breeding season, varies from 4 to 6 days in length.

The period of gestation of *Sigmodon hispidus* has been determined by Seth B. Benson to average 27 days.

The fertility relationships between the members of the same species-group are being studied in the *Peromyscus leucopus* group, in the *boylii* group, and

in the *truei* group. In the *leucopus* group all of the subspecies of *Peromyscus gossypinus* and *Peromyscus leucopus* so far tested have proved to be fertile together, producing fertile offspring. Considerable difficulty has been found in getting different stocks of *Peromyscus boylii* to breed together. While the individuals within one local population have been quite fertile together in the laboratory, mice from the Santa Catalina Mountains have been relatively infertile when mated with mice from the Huachuca Mountains. This is true notwithstanding the fact that these two stocks are members of the same subspecies. Only one litter has been produced from this cross and these young were killed by the parents or died shortly after birth. In the *maniculatus*, *leucopus*, *truei* and *eremicus* groups, different stocks of the same subspecies and species are almost always fertile together.

Considerable progress has been made on the report of the relationships between soil colors and pelage colors of mammals in Arizona and Sonora. The tint-photometer readings have been practically completed and the report is in rough manuscript. Another of the rock-inhabiting rodents of the nearly black Pinacate lava in northern Sonora has been described by Philip Blossom as a new subspecies. This is a form of the desert woodrat, *Neotoma lepida bensoni*, distinguished by its blackish pelage.

A serological study of the various species of *Peromyscus* is being conducted by Dr. Paul A. Moody of the University of Vermont to determine the physiological relationships within the group. The mice of this genus prove to be so closely related that distinguishing between their sera by the ordinary precipitin tests is difficult and apparently impracticable. Consequently an attempt is being made to apply to the study the Dale anaphylactic test. The latter involves the sensitization of female guinea-pigs to deer mouse serum, the removal of the uterus and the suspension of portions of the uterine horns so that their contraction upon administration of dilutions of deer mouse serum will be recorded as tracings upon a kymograph. The maximum dilution of the homologous serum causing contraction is compared to the maximum effective dilution of the serum from a second species. The ratio of these end-points gives a measure of the relationship of the two deer mouse species concerned.

Just, E. E., Howard University, Washington, D. C. *Zoological researches*.
(For previous report see Year Book No. 33.)

The following reports have been submitted by Dr. Just covering extension of studies undertaken by him with aid of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

According to my theory of the ectoplasm, the superficial cytoplasm of the living cell plays a definite rôle in vital phenomena. This is not to say that I assign to the ectoplasm the chief part in life-activities to the exclusion of other cell-components. Rather, I regard the whole protoplasmic mass as the biological unit and conceive all manifestations of life as consequent to and expressive of the cellular constituents which both in space and in time give protoplasm that organization, as defined by Brücke, its peculiar place in the natural world. Moreover, while many protoplasmic masses, as certain bacteria, fail to reveal discrete nuclei, though they may contain nucleic acid, as shown by researches that give evidence of the presence

of this acid, and though many cells are multinucleate, no living cell exists without surface-structure. Cells, obviously, do not extend indefinitely in space. The ectoplasm of any mass of living protoplasm exhibits differentiation from the inner core of cytoplasm, the endoplasm, because of its physical properties. This ecto-endo-plasmic differentiation prevails in living matter though nucleo-cytoplasmic differentiation may be absent or obscured.

With respect to the structure of the ectoplasm, the biological literature contains a mine of observations. Some of this includes "undesigned testimony," often the best of evidence. Henle, Kölliker, Weismann, Haeckel, Schultze and Maas, the German investigators, Kowalewski and Metschnikoff, the Russians, Vedjovsky, Whitman and G. F. (Mrs. E. A.) Andrews especially may be mentioned among those who have pointed out the structure of the surface-cytoplasm of cells. Mrs. Andrews particularly emphasized the significance of the cell-surface in vital activity. Investigations on the ectoplasm of animal cells include protozoa, tissue-cells and eggs. In passing, I may call attention to the fact that in most plant-cells the living protoplasm is a sheath of substance which encloses inert matter.

It is not only in the cells mentioned above that the ectoplasm has been demonstrated. In cells grown outside of the organism of which they have been a part, the ectoplasm has been abundantly studied. Thus, by this epoch-making method of tissue culture, Harrison proved that the growth of the vertebrate nerve-fiber is due to ectoplasmic prolongations. Other cells as well, he found, exhibit pronounced ectoplasmic activity when in tissue-culture. While all too frequently subsequent work on tissue-cultures has had about as much ulterior motive as a small boy whittling a stick with his new knife, Harrison's work stands not only as the foundation of a new method of biological research, but also as that which answered the then hotly debated question of the unit-structure of the nerve-system. His and all subsequent work prove that all cells grown in tissue-culture possess ectoplasm, and that this exhibits definite behavior.

During the year January 1934 to January 1935, I had the opportunity while at the Zoological Station, Naples, to extend my own observations and experiments on ectoplasmic structure and behavior in egg-cells. The results obtained have made it possible to fortify and to elaborate my conception of the rôle of the ectoplasm in vital activity. In previously published work, I have pointed out that the ectoplasm or superficial cytoplasm plays a necessary rôle in fertilization. Evidence of substantial weight I have adduced to show this necessity of the ectoplasm for parthenogenesis, cell-division, chromosome-behavior in heredity and in cancer. The ectoplasm plays a leading part in differentiation of development.

Observations were made and experiments set up in the study of a large number of eggs of various species available at Naples in order to learn more concerning the spatial and temporal structure of the ectoplasm. The results of some of this work will be embodied in forthcoming publications; some must be repeated and other parts continued. For the present I may say that the ectoplasm is a living continuation of the hyaline ground substance of the cell, is in constant activity and never in the same state during the development of the egg. By observing its activity, one can by experi-

mental treatment modify the development at will in several directions. One needs only to know the characteristic behavior of the egg under experiment and the stage of its development, in order to give the egg the treatment when the ectoplasm shows that precise behavior peculiar to the specific egg in the particular stage of its ontogeny. With the temporal and spatial behavior of the ectoplasm known, one can time experimental treatment at one-minute intervals and obtain most profound alterations of the course of development.

Along with this work, experiments were carried out on the rearing in the laboratory from eggs to sexual maturity of a species of sponge of a coelenterate, and of two species of worms. I also reared to sexual maturity *Ciona*. In addition, I carried three species of sea-urchins through sexual maturity. My purpose in most of this work was to get the best possible information of the life-histories of the animals as a basis for an elaborate series of experiments on the physiology of development. Much of our experimental embryology is weak because we do not have sufficient information concerning any but the beginning stages of the normal development. Too frequently both the normal and the experimental study ends too abruptly.¹

The more specific reason for rearing *Ciona* from eggs fertilized in the laboratory was pointed out in an earlier report. Further information is as follows:

(1) Eggs from animals reared to sexual maturity are capable of self-fertilization, as are those taken from mature animals shortly after collection of the animals. Eggs from either type of animal show a gradual falling off in capacity for self-fertilization during successive days in the laboratory when they are kept each isolated in a separate container. Eggs from pairs of animals show precisely the same drop in "cross"-fertilization. Loss of fertilization-capacity can be correlated with the lowered physiological condition of the animals which discharge the eggs. Failure of self-fertilization is due to the poor condition of the gametes. Where, as has been reported, self-fertilization fails, while "cross"-fertilization between two such animals succeeds, I conclude, on the basis of my own work, that the failure is due to differential retrogression of the gametes and to differences in the concentration of the spermatozoa around the eggs. Presence of the coelomic fluid also inhibits fertilization.

(2) A finding on *Ciona*, which because of my experiences with rearing marine animals under laboratory conditions did not astonish me, may be noted. This is that animals, even those which had attained a length of 4 cms., often were sterile. On the other hand, *Ciona* of 1 cm. and less, collected in the Bay of Naples, were fully mature and shed eggs that gave 100 per cent fertilization.

(3) *Ciona* raised in the laboratory were found to have high capacity for regeneration. When transected, the forward region of the animal (bearing the syphons), under proper conditions of light, sea-water and food, regenerated. I hope to continue this work. Previously, workers, e.g. J. Loeb and

¹ In this connection, see Mortensen on the *Development and larval forms of Echinoderms*, Copenhagen, 1921, especially pages 4 to 5.

Huxley, among others, have reported regeneration in this and other ascidians; but no one has reported the degree of regeneration which I have observed.

Longley, W. H., Goucher College, Baltimore, Maryland. *Preparation of a monograph of Tortugas fishes.* (For previous reports see Year Books Nos. 31-33.)

Excellent facilities for work placed again at my disposal in the museums of natural history in London, Paris, Bologna, Vienna, Berlin and Amsterdam, from February to May inclusive, opportunity to examine anew the rich collections of the Museum of Comparative Zoology of Harvard University and the U. S. National Museum, to inspect critical material in the American Museum of Natural History and the Bingham Oceanographic Collection increase my indebtedness to the direction of the several institutions, more fitting acknowledgment of which must be made on another occasion.

With such resources as are indicated freely available, time alone limited progress in determination of the valid species of West Indian fishes. This progress has been gratifying and a few observations have been made as well upon the validity of genera.

Caularchus Gill and *Caulistius* Jordan & Evermann appear to have no claim to generic recognition in the Gobiesocidæ. In dentition, number of vertebræ and in fin formulæ *Caularchus mæandricus* (Girard) differs no more from unquestioned species of *Gobiesox* than these do from one another. And except for number of vertebræ (unknown in the unique type of *Gobiesox papillifer* Gilbert, the genotype) the same may be said of *Caulistius*.

A change of reverse order is necessary in the Mullidæ. Species Jordan, Evermann and Clark (*Check List*, 1930, 343) refer to as *Upeneus maculatus*, *U. martinicus* and *U. parvus* are no two of them congeneric, as Poey recognized (*Enumeratio*, 1875, 34).

The relations of a number of nominal species are as follows, not all the names in synonymy being here so placed for the first time:

Apogon gloverensis (Mowbray) = *Apogon conklini* (Silvester)

Mycteroperca camelopardalis (Poey) = *Mycteroperca tigris* (Cuvier & Valenciennes)

Mycteroperca chlorostoma (Poey) = *Mycteroperca phenax* Jordan & Swain = *Mycteroperca calliura* Poey = *Mycteroperca falcata* (Poey) = *Mycteroperca dimidiata* (Poey) = *Mycteroperca interstitialis* (Poey)

Calamus pennatula Guichenot = *Calamus orbitarius* (Poey) = *Calamus quadrituberculatus* (Ranzani)

Calamus kendalli Evermann & Marsh = *Calamus macrops* Poey = *Calamus calamus* (Cuvier & Valenciennes)

Eucinostomus harengulus Goode & Bean = *Eucinostomus jonesii* Günther = *Eucinostomus pseudogula* Poey = *Eucinostomus argenteus* Baird & Girard

Chætodon consuelæ Mowbray = *Chætodon striatus* Linnæus, *juv.*

Chætodon littoricola Poey = *Pomacanthus quinquecinctus* Cuvier & Valenciennes = *Pomacanthus cingulatus* Cuv. & Val. = *Pomacanthus lutescens* (Bonnaterre) = *Pomacanthus paru* (Bloch) = *Pomacanthus arcuatus* (Linnæus)

Pomacanthus rathbuni Miranda Ribeiro = *Pomacanthus balteatus* Cuvier & Valenciennes = *Pomacanthus luteus* (Bonnaterre) = *Pomacanthus aureus* (Bloch)

**Holacanthus lunatus* Blosser = *Holacanthus ciliaris* (Linnæus), *juv.*

**Scorpena occipitalis* Poey = *Scorpena inermis* Cuvier & Valenciennes

**Scorpena atlantica* Nichols & Breder = *Scorpena calcarata* Goode & Bean

†*Auchenopterus affinis* (Steindachner) = *Auchenopterus monophthalmus* Günther

Brommophycis verrillii Garman = *Dinematichthys cayorum* (Evermann & Kendall)

Gobiesox androsiensis Rosen = *Gobiesox rubiginosus* (Poey)

Gobiesox barbatulus Starks = *Gobiesox gyrynus* Jordan & Evermann = *Gobiesox nigripinnis* (Peters)

?*Gobiesox yuma* Nichols = *Gobiesox vittatus* Metzelaar = *Gobiesox punctulatus* (Poey)

Gobiesox tudes Richardson = *Gobiesox cephalus* Lacépède

This list includes a number of cases in which confusion regarding identity has been unusually great. The diagnostic characters of these species, however, when once they are made out, prove upon the whole to be as distinct as one might wish.

As the investigation here reported upon nears its end, it appears that the species concept is sound, that what in the taxonomic record are rated species are for the most part very distinct, and that the evidence for intergradation is almost exclusively due to illusion.

First, young and old, male and female, different transitory color-phases, the well and the poorly preserved, the well and poorly described of a single species are entered in the record under different specific names, not rarely as many as five times and often in different genera. Then from these categories, erected without trace of biological justification, the superficial student infers that a species is anything which has been so called and that nothing is real but the individual.

The conclusion is false. All that may justly be called species are groups objectively given, through study of which direct and effective attack upon the species problem has been and still is possible.

Morgan, T. H., C. B. Bridges and Jack Schultz, California Institute of Technology, Pasadena, California. *Constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15-33.)

The study of the enormous salivary chromosomes has been continued, by Bridges, both as found in wild strains and in various aberrations which had been first studied genetically. In general the condition of the salivary chromosomes in different normal strains is remarkably uniform, but certain strains seemed invariably to show unusually small crinkled chromosomes, while one race (Swedish B) had larger more diffuse chromosomes in all individuals studied. In the case of certain wild strains and of some mutant

* Corrects mistakes of mine in earlier reports of this series.

† This must be struck from the list of West Indian species. It is known only from the West Coast of America.

rices not known to carry inversions, the examination of the salivary chromosomes disclosed the presence of inversions. Since it is a matter of prime importance that genetic studies should be free from disturbances due to chromosomal aberrations it seems advisable, in the future, to precede any large scale genetic study by a salivary examination of the strains prepared for the experiment.

The cross-banding present in the normal salivary chromosomes has been studied with respect to the constancy of given bands, the range of structure shown by the banding, and a region-by-region census of the bands. From series of camera lucida drawings of chromosomes stretched to the optimum amount, maps have been prepared, covering the entire chromosome complex (Published in Journal of Heredity, Feb. 1935). The average lengths of the moderately stretched salivary chromosomes as drawn were: 1(X) = 220μ , 2 = $215 + 245 = 460\mu$, 3 = $210 + 275 = 485\mu$, 4 = 15μ , total 1,180 μ . Since the total length for the gonial chromosomes is only 7.5 μ , the salivary chromosomes are approximately 150 times as long, and show a wealth of internal structure in contrast to the mere silhouettes shown by gonial chromosomes.

The total number of distinct cross lines appearing in the published drawings was found to be over 3500. But subsequent more intensive study of certain regions has shown many lines not hitherto observed, and suggests that the total number will approach 5000 when similar studies have been made for the whole complex. The increase in the number observed comes from the detection of faint or fine lines in regions that have appeared to be "clear," and also many lines have been resolved into two when the bands are sharper, due to a better optical system and to a more suitable amount of stretching of the chromosomes.

A considerable proportion of these $5000 \pm$ "lines" seems to be double structures with an indistinct split into halves. In case such a line shows the 16 distinct "chromioles" of which it is composed, each such chromiole resembles the halves of an almond shell. The site of the main body of the gene may be conceived as situated between these two half-shells. On this view it would appear that the shells represent deposits of chromatin at the two polar extremities of the unstained gene body and that, extending beyond each of these deposits of chromatin, there is a fibrous outgrowth which is fused end-to-end with that of the next gene in the series and forms the achromatic zone observed between adjacent distinct cross-bands.

On the assumption that a gene locus corresponds to each cross-band of dots, dashes or tiny vesicles, and also to each pair of closely approximated thin matched lines, the number of loci present in *Drosophila melanogaster* should lie in the neighborhood of 4000. Some of the calculations from genetic data as to the number of genes have yielded estimates from 1800 to 5000 and are not in disagreement with this value.

A system of reference of each band to a numerical location has been devised and in a year's use has proven both accurate and elastic. The method is to divide the total length of the large chromosomes into 100 numbered divisions, 20 to each of the five main limbs. The sections are numbered 1 through 20 for X, 21 through 40 for 2L, 41 through 60 for 2R, 61 through 80 for 3L, and 81 through 100 for 3R. Chromosome 4 has sections

101 and 102. Hence the number of a section is itself a key to the chromosome limb and to the relative position along that limb. Each section begins with a conspicuous and easily recognized band. The division point between sections is always made just to the left of the chosen main band, leaving minor bands in the section to the left of it. But since the 102 divisions average about 40 bands each it was found advisable to subdivide each division into six sub-divisions, designated by the letters A, through F. Each sub-division likewise begins just to the left of a sharp band. A particular band would then be referred to as 17B3.

A further analysis of the salivary chromosomes of the first translocation found in *Drosophila*, viz. the "Pale" translocation, shows that the case is more complex than the simple excision of a section from near the right end of 2R and its intercalation in reversed order, into 3R. The deficiency in 2R includes a section of about 50 bands, beginning with 58E4 and extending through 60E1. The corresponding duplication is inserted smoothly as a normal appearing section of chromosome 3R, without side attachment (originally suggested) and without any obvious feature which would account for the finding by Hamlett that the female homozygous for this duplication-bearing 3R has markedly lower crossing-over. Apparently there are three discrepancies between the deficiency and the duplication-bearing chromosome. The first is that band 58F1, and probably a lighter band on each side of it, are not recognizably included in the duplication, although they are included in the deficiency. This agrees with the early assumption (made to account for the eye-color and lethal effects of Pale-translocation) that the duplication is not as long as the deficiency. The second discrepancy is that band 96B5 (a strong double line) is present at the left boundary of the inserted duplication and also (or a line of similar morphology) at the right boundary. This line at the right boundary would seem to be a duplication of band 96B5. The third discrepancy is that to the right of band 96B5 follow a light and two medium bands which have not been homologized with bands either of the second chromosome deficiency region or of the third chromosome in the region of the insertion.

The extreme selectivity of the agency which brings about "synapsis" of homologous bands is well shown in the Pale-translocation where the very small fragment of 2, which is inserted into 3R, fuses band-to-band with the homologous section which is part of the normal 2R, in spite of the drag offered by the rest of 3R and the rest of 2R.

The synaptic fusion of homologous bands serves as a clue to the presence of certain bands and even of long sections of bands present simultaneously at two places within this *normal* complement. Thus it was noted that in the basal region of 2L there were two extensive regions in which the chromosome was thrown into a spiral loop with fusion of the chromosome parts near the ends of the loop. When these loops are pulled apart in smearing the nucleus, protoplasmic strands can often be observed connecting band-by-band the parts that were in contact. Examination of these bands showed that they matched in two series and hence were presumably repetitions of the same series of bands. In other places "reversed repeats" were found, in which the two series ran in both directions from a midpoint of symmetry. This discovery confirms the hypothesis that the normal evolutionary increase

in number of genes has been by "duplication" of the previously existing genes, followed by diversifying mutation.

With the assistance of Viola Curry, an extensive analysis of the incidence of simple and multiple crossing-over throughout the length of the X chromosome has been completed. Nine well-spaced loci (*sc*, *ec*, *cv*, *ct*⁶, *v*, *s*, *f*, *car*, *bb*) were followed, which allowed the observation of all crossing-over between scute and bobbed which lie at the ends of the chromosome. The inviability effects were neutralized by an "alternated" arrangement of the mutant characters. The bobbed locus was treated as a lethal by using bobbed in the heterozygous mothers and bobbed-lethal in the multiple recessive

Crossing-over throughout the X-chromosomes of Drosophila melanogaster

Loci— Intervals—	sc 1	ec 2	cv 3	ct 4	v 5	s 6	f 7	car 8	bb
Cultures = 220	1, 6 = 118	4, 7 = 159	1, 5, 7 = 2	3, 5, 7 = 2					
0 = 6,607	1, 7 = 54	4, 8 = 91	1, 5, 8 = 1	3, 5, 8 = 3					
	1, 8 = 34	5, 6 = 35	1, 6, 8 = 1	3, 6, 7 = 1					
1 = 506	2, 3 = 3	5, 7 = 49	2, 3, 6 = 1	3, 6, 8 = 1					
2 = 1,049	2, 4 = 38	5, 8 = 40	2, 4, 6 = 4	4, 5, 8 = 1					
3 = 855	2, 5 = 85	6, 7 = 21	2, 4, 7 = 5	4, 6, 8 = 4					
4 = 1,499	2, 6 = 237	6, 8 = 30	2, 4, 8 = 6	4, 7, 8 = 1					
5 = 937	2, 7 = 123	7, 8 = 2	2, 5, 6 = 3	5, 6, 8 = 1					
6 = 1,647	2, 8 = 70		2, 5, 7 = 4						
7 = 683	3, 4 = 22	1, 2, 3 = 1	2, 5, 8 = 1	N = 16,136					
8 = 379	3, 5 = 55	1, 2, 6 = 1	2, 6, 7 = 2	Non. = 6,607 = 40.9%					
	3, 6 = 177	1, 3, 5 = 1	2, 6, 8 = 3	Sing. = 7,555 = 46.8%					
1, 2 = 3	3, 7 = 88	1, 4, 5 = 1	2, 7, 8 = 2	Doub. = 1,913 = 11.9%					
1, 3 = 6	3, 8 = 38	1, 4, 6 = 1	3, 4, 7 = 2	Trip. = 61 = 0.4%					
1, 4 = 41	4, 5 = 41	1, 4, 7 = 2	3, 4, 8 = 1	Quad. = 0 = 0.0%					
1, 5 = 55	4, 6 = 198	1, 4, 8 = 1	3, 5, 6 = 1						
Interval	1	2	3	4	5	6	7	8	Σ
Tot. Recomb.	5.14	10.17	7.79	13.14	8.17	15.43	7.45	4.41	71.70

fathers. The offspring were raised at 19°C., since at higher temperatures around 25°C. the character sable is heat sensitive and unreliable in classification. In the table is presented a summary of the data obtained and in figure 1 are given the recombination curves and the curves for transforming recombination values into map distances. Analysis of the data in terms of four strand crossing-over and of the tetrad series are being carried out with the assistance of Dr. Don Charles.

A study by Schultz of translocations G and H, involving the second and the Y chromosomes, has given information as to the somatic effects of the duplicate or "repeat" regions, discovered by Bridges in the chromosomes of the salivary gland cells. Translocation H includes the whole of a repeat region in chromosome 2L, from band 37B2 to 40B2 (Bridges' reference system). Translocation G is longer, extending from 36B5 to 40F—a section including approximately 104 bands. Deficiency G is lethal in the heterozygote; Deficiency H is a slight Minute, somewhat sterile. But the net deficiency produced by combination of Deficiency G and Duplication H is an extreme Minute, as has been stated in a previous report. This means that a deficiency for 70 bands, which include a duplicate section of chromosome.

has less somatic effect than one for 34 bands in an adjacent region (the net deficiency G-H), containing no observed duplicate section. The indications are, therefore, that in the case of the "repeat" regions, as in the case of the sex chromosomes, there has been developed a "buffering" mechanism which minimizes the effects of dosage change.

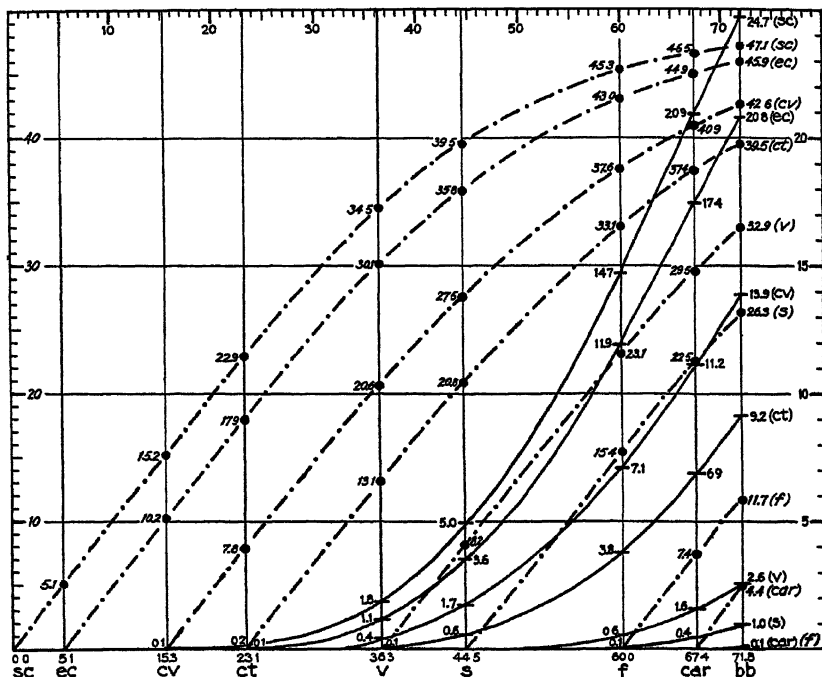


FIG. 1—Curves of numerical differences (ordinates) between values for recombination and corresponding crossing-over (abscissae) [scale to right, solid lines, cross-bars, Roman numerals]. Curves of recombination values (ordinates) corresponding to given map-distances (abscissae) [scale to left, dot-dash lines, solid circles, italic numerals].

The study of variegated strains with special attention to their relation to "inert" regions has been continued by Schultz. Three rules may now be formulated, which cover the thirteen cases he has studied and some cases already described by others. (1) Variations are correlated with rearrangements involving inert regions, as a result of which genes, normally distant from the chromocenter of the salivary gland nucleus, are brought to its immediate vicinity. By the coalescence of the "inert" regions with the chromocenter, these rearrangements may form abnormal configurations, such as rings or lateral attachments. (2) The frequency of variegation is a function of the balance of inert regions as compared to active regions (*i. e.*, it may be changed by adding or subtracting Y chromosomes). (3) The variegations may be interpreted in terms of the loss or rearrangement of genes in the portion brought to the chromocenter, as a result of which mutational "position" effects may occur in neighboring genes.

An attempt has been made to formulate a scheme for these variegations on the basis of the method proposed by Belling for gene reproduction. The variegation arises from deficiencies, or from position effects of rearrangements, which have come about through abnormal reproduction in twisted ring chromosomes or chromosomes with lateral attachments.

A relation of inert regions of the Y to the fertility of the male had been inferred from the sterility of the X0 male (Bridges) and from the sterility of males containing various fragments of Y chromosome (Stern). It appeared that the fertility genes of the Y had no relation to the inert region of the X chromosome, since a male deficient for the inert region of the X was still fertile in the presence of a normal Y. Recently Schultz has found that translocations involving the Y chromosome produce fertile males in the presence of a normal X, but give sterile males when combined with either one of the two bobbed deficiencies in the X. Bobbed-lethal does not produce sterility, showing in this respect a similarity to the cases of bobbed "mutations" in deficient X chromosomes studied by the Dobzhanskys, in which the bobbed effect appeared with bobbed deficiency but not with bobbed-lethal. The sterility of males in these cases, like all the others involving a Y chromosome effect, depends on the immobility of the sperm. These sterility effects apparently have then a common basis in X and Y, and the factors in the Y undergo some sort of position effect in the translocations.

The cytological study by Schultz of a Y deficient for bobbed has shown that the bobbed locus is present, as Kauffman believed, in the short arm of the Y (reduced in size in the deficiency) and not in the long arm as Stern had previously concluded. An attempt has been made to obtain a further check of the location of bobbed by study of "detachments" occurring in females which carry attached X chromosomes homozygous for bobbed, and a normal Y chromosome. Three detachments were obtained, all carrying the bobbed allelomorph present in the attached X's. One shows a J-shaped chromosome in the gonial cells; the other two show separate normal X chromosomes. It appears that in addition to detachment through the interchange between the attached X and Y chromosomes, such as Kauffman found in normal attached X's, a process of detachment through fragmentation may also occur.

In the salivary gland chromosomes, Painter has indicated the bobbed locus to be one of two bands next to the chromocenter region of the X; in favorable material the Y can be seen as a band (possibly two) synapsing with this, which Schultz has identified as 19F from a study of bobbed deficiency.

By a comparative study of types differing in the number of Y chromosomes it has been found that the Y is somehow concerned with the "turgor" of the chromosomes in the cell—the more Y chromosomes, the darker the staining and the "stiffer" and plumper the chromosome. This effect may be related to the development of the chromosome matrix or sap.

Flies carrying closed X chromosomes show not infrequently small mosaic patches, corresponding to mutants in the chromosome opposite the closed X. The frequency of patches is increased in the triploid but is still low. To determine the behavior of small X ring-chromosomes an attempt was made by Schultz to obtain them by X-raying males which carried a closed X.

and looking for X chromosome duplications in their progeny when mated to attached X females. Eleven individuals with deficient X chromosomes were obtained, but not one could be bred because of sterility. Eight occurred as very long duplications and would be expected to be sterile. That so many should be long duplications is unexpected; since in a comparable experiment involving the irradiation of normal X, more than half the deficient X's produced were found as short duplications. The closed X chromosome is probably differently oriented in the sperm than is a normal X chromosome, and the deficiencies presumably caused by attachment and breakage of overlying chromosomes tend to be of the longer type.

In collaboration with Dr. A. H. Sturtevant, Schultz has made a study of various scute allelomorphs. In the salivary gland chromosomes the scute gene has been associated with the band 1B2 and proof obtained that a deficiency for this gene survives in the adult. Similar survival of a deficiency has been found for the genes yellow and achæte, confirming on different material Muller's earlier result. Certain of the scutes, in agreement with the findings of Muller and Prokofyeva, are associated with rearrangements near the scute locus (scute², scute⁴, scute⁷, scute⁸, achæte⁸). Others (scute³, yellow scute^{D1}, and scute^{D1}) show normal salivary gland chromosomes. It appears therefore that not all mutations at this locus belong to the category of gross position effects, and also that the simultaneous occurrence of two closely linked mutations, y and sc D¹, is not necessarily the consequence of a rearrangement.

The study of interchromosomal effects in crossing-over has been continued. New data have been obtained, and a detailed presentation of the full material is in preparation in collaboration with Dr. Helen Redfield.

The exceptional daughters of XXY mothers have been shown by Bridges to be non-crossovers for the X chromosome. A comparison has been made by Schultz of the crossing-over in an autosomal region, in exceptional females and their regular sisters, which undergo crossing-over in the X chromosome. XXY; Plum¹/+; D⁸H/+ females were mated to Bar males. The D⁸-H crossing-over in the 8609 regular offspring was 17.09 ± 0.0004 per cent; in the 159 exceptional offspring the percentage was 33.34 ± 3.4 ; the difference between the two being 16.25 ± 3.76 . Clearly the decrease of crossing-over in one chromosome has resulted in a compensating increase in another.

The XX sisters of the XXY mothers of the experiment above showed the effect of a supernumerary Y on crossing-over in an autosome: the XX females gave a D⁸H value of 10.3 ± 1.37 per cent, while the XXY females (total progeny) gave 17.39 ± 0.004 .

These results, and those presented in previous reports, may be understood in terms of the following assumptions: (1) Crossing-over is a function of the twisting of chromosomes about each other. (2) At the last gonial telophase, the homologous chromosomes tend to be associated, due to somatic pairing. (3) The change from telophase to resting stage involves an extension of the chromosomes between spindle attachments and ends.

From these assumptions it follows: (1) Crossing-over should be less frequent, per unit of cytological length, at the regions near the spindle attachments and near the ends of chromosomes—this gives immediately the so-

called "spindle-fiber effect" and the discrepancy between genetic and cytological maps. (2) The disturbance of somatic pairing in one chromosome pair in the last premeiotic division entails an increased likelihood of overlying contacts, or twists near the spindle fiber of that pair of chromosomes when they do synapse in prophase; and this overlap will be correlated with a similar occurrence in another pair. This would account for the positive correlation of crossing-over near the spindle attachment region of normal chromosomes, and interference gives the negative correlations found elsewhere. (3) Unpaired chromosomes, or inversions, or the frequent disturbances of somatic pairing in triploids should give rise (as they do in fact) in the pairing of normal chromosomes to an increase of crossing-over, proportionately greatest near the spindle attachment. This would occur as a result of increased frequency of overlap in those chromosomes which pair in spite of the mechanical obstructions offered by the unpaired or looped chromosomes.

Schultz has found that mature *Drosophila* sperm are killed, either in the male or in the fertilized female, by exposure for an hour to anaerobic conditions. This is similar to other cases already known. for example, the sperm of *Nereis* are likewise sensitive to anaerobiosis. The treatment is of technical value in *Drosophila*, since females already fertilized may be treated with proper exposure of anaerobiosis and remated as if they were virgin.

By the appropriate combination of different translocation derivatives, Schultz has synthesized a homozygous five-chromosome race of *Drosophila melanogaster*. This will be useful in studies of the relation of the spindle attachments in crossing-over and disjunction, as well as for experiments in the construction of races which when crossed should give sterile hybrids.

GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis*. (For previous reports see Year Books Nos. 25-33.)

When this project was inaugurated in 1925 the principal objectives in view were (1) to demonstrate the value of a combined attack by genetic, cytologic and taxonomic methods on problems of systematic classification in a large and complex group of plants; (2) to determine the method of origin of the differences between the species in the group; (3) to create new species.

That the first objective has been achieved in part is shown by the published results of these investigations, especially by the report of Babcock and Cameron on 108 species of *Crepis*, cited in this Year Book. A more complete demonstration awaits publication of other papers, particularly the monograph on *Crepis*, the preparation of which is going ahead as rapidly as possible.

The second objective has been approached through the study of the nature of the evolutionary processes involved in the origin of species. This study has not involved an attack on the third objective (experimental production of new species) so much as the deduction of conclusions from the synthetic treatment of data on existing species. These data are mainly of three categories, comparative morphology, geographic distribution, and chromosome number and morphology, while additional evidence came from the results of experiments in intra- and interspecific hybridization. It is clear that evolution in *Crepis* involves at least four genetic processes—chromosomes transformation, interspecific hybridization, polyploidy, and gene mutation. For further discussion of these conclusions and the evidence on which they are based see the report of Babcock and Cameron mentioned above.

Growing out of the study of geographic distribution in relation to chromosomes and phylogeny in *Crepis* and related genera, a new hypothesis as to the origin and development of the subtribe Crepidinæ has been suggested. This was outlined in the preceding Year Book (p. 283) and will be discussed more fully in a paper on the origin of *Crepis* and related genera, with particular reference to geographic distribution and chromosome relationships, to appear in the University of California Publications in Botany (Setchell Festschrift Volume).

As a result of the intensive study of *Crepis* and the preliminary survey of the Crepidinæ, a new point of departure was reached and it was realized that this called for cytogenetic and taxonomic research on several genera, especially on *Prenanthes* and *Lactuca*. Accordingly plans for a new project were prepared and a three-year grant was obtained from the Rockefeller Foundation which makes possible the engagement of two research associates on a full-time basis, Dr. G. Ledyard Stebbins jr. and Dr. James A. Jenkins.

The general plan of procedure is similar to that which has been followed in the *Crepis* investigations. But, in order to speed up the cytogenetic research as much as possible, special effort must be made to obtain a considerable number of species in living condition. This calls for the activities of many collectors in various parts of the world during the next year or two and some of these collectors require financial reimbursement. Meanwhile some

living material is already available for cytological study and the preparatory taxonomic research is well under way.

During the past year the writer has been assisted in the *Crepis* investigations by Dr. D. R. Cameron, Mr. J. A. Jenkins and Dr. Olive Swezy, all working on a part-time basis. Cytogenetic studies on small groups of *Crepis* species have been carried on by Dr. D. R. Cameron, Dr. Olive Swezy, and the following graduate students: Mr. J. A. Jenkins, Mrs. Marion S. Cave and Mr. F. L. Smith. In general these studies on closely related species, having chromosomes of very similar morphology, tend to support the conclusion that gene mutations (and possibly minute structural changes which do not greatly affect the morphology of the chromosomes) comprise an important category of evolutionary processes in *Crepis*. But these minor changes in composition or structure of the chromosomes seem to play a secondary rôle. That is, they accompany or follow after those more profound changes in structure or number of the chromosomes which make possible the origin of major genetic complexes. Given these new departures, then gene mutations and minor structural changes provide the genetic means for differentiation into groups of closely related species.

A study of the somatic chromosomes of *Crepis biennis* L. and *C. ciliata* C. Koch was undertaken by Dr. Olive Swezy and the writer because the chromosome number in these two European species ($2n = 40 \pm$) indicates polyploidy and because cytogenetic evidence¹ showed that *C. biennis* is an octoploid. Analysis of chromosome types in this species reveals the existence of a double basic genom containing five distinct types, with two representatives of each type which differ in certain details. Hence *C. biennis* may be an allo-octoploid which originated through hybridization between two 5-paired ancestors which differed somewhat in chromosome morphology. Most likely hybridization was followed by amphidiploidy and this by a second doubling. In *C. ciliata* a similar situation is found but the differences between the two representatives of each of the five chromosome types are less marked. This species may have had a similar origin to *C. biennis* or it may be an auto-octoploid. The evidence on mode of origin of these two species adds further proof that 5, not 4, is the primary chromosome number in *Crepis*. By analysis of such cases it is possible to derive working hypotheses as to the genetic nature of polyploid species which may lead to further knowledge of their nature and origin. In general, tetraploidy is the antecedent of autopolyploidy, and allo-polyploidy in one or both parents is sometimes associated with autopolyploidy in species hybrids. Further, autopolyploidy provides a favorable mechanism for the origin of new species with quite different chromosome numbers.

Davenport, Charles B., Cold Spring Harbor, New York. *Investigation on Child Development*.

During the year under review I prepared the Annual Report of the Department of Genetics and then, in accordance with understanding with the President of the Institution, prepared the manuscript of a book on child development from the standpoint of genetics. This is now being considered by

¹ Genetics, vol. 8, 212-232, 1923; vol. 14, 305-320, 1929.

publishers. I have also nearly completed, with the assistance of Mr. Merle P. Ekas, the fourth edition of "Statistical Methods."

During the period under consideration cooperation with Letchworth Village was continued on the study of growth of about one-hundred children from juvenility to puberty from the standpoints of physical development, of physiology and of psychology. The physiological section, under Miss Olive Renfro of Letchworth Village, deals with basal metabolism, bone development including that of the sella turcica in which lies the pituitary gland, vital capacity, dynamometrics and blood counts. The psychological testing is under the general supervision of Dr. Elaine F. Kinder of Letchworth. The studies on physical development of about twenty infants at the Normal Child Development Research Clinic, Columbia University—Presbyterian Hospital Medical Center, has been continued. They have involved fortnightly visits.

A study has been published on the development of the human trunk. The shoulder width of girls exceeds that of boys temporarily, during the adolescence of the latter, on account of the precocity of the adolescence of the girls. The Negro shoulder grows faster than that of the European. Corresponding with differences in the type and velocity of body-growth as a whole, there are differences in form of the growth curve of the shoulder in individuals. Shoulder width in relation to stature steadily declines in shoulders of whites from 6 to 14 years, since the trunk breadth lags, in velocity of growth, far behind that of the legs; but after 14 years the relative shoulder width increases. However, in colored (Negro) children the juvenile-adolescent decline is less marked. Shoulder breadth in relation to length of trunk rises slightly during juvenility and declines during adolescence and rises again during puberty. The human pelvis, which is one of man's most unique features (associated with his upright posture), is during juvenility smaller in the Negro male than in the white, but after puberty this relation is reversed. It also varies in the growth of the individual with his type of body-growth as a whole. But in relation to stature as a whole, pelvic width declines to adolescence and thereafter increases slightly, and the colored boys have a smaller ratio than the whites. The same is true when the pelvic width is taken in relation to trunk length. When the growth of pelvic width is compared with that of shoulder width, it appears that during late fetal life the pelvis grows faster than the shoulders, since the pelvis starts development later than the shoulders. But early childhood is a time when the shoulders grow the more rapidly. In adolescence, the pelvis again takes precedence in velocity of growth. When transverse chest diameter is used as the measuring rod, it appears that the pelvis (anterior iliac spine interval) grows relatively rapidly in both sexes before birth, then more slowly, and decreases during adolescence, to pick up again at puberty.

The adult human shoulder is unique among mammals in its broad lateral extension, permitting not only free lateral movement but also movement in front of and behind the vertebral axis. The scapulæ when first well developed lie at an angle of 60° or more with the frontal plane, at birth about 50° and in the adult about 30° . The acromial processes thus come to project laterally more and more prominently. This metamorphosis of the shoulder carries the child from the type of the lower mammals to that of *Homo*.

Thus from the fourth month of gestation to even past maturity, the proportions of the trunk are undergoing marked changes by which the embryo and child become adult. The upbuilding goes to a considerable extent along the lines of the upbuilding of Primates and other mammals. But at an earlier or later stage the course of differential development becomes specifically human. Recapitulation in development is parallelism in development up to the point when each species begins to produce its differential parts.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-33.)

As emphasised in the last annual report, our work is concentrated upon the production of new, entirely recast editions of volume I, "Statics," and volume II, "Kinematics" (Carnegie Inst. Wash. Pub. No. 88, 1909-11) of *Dynamic Meteorology and Hydrography*, and upon the working-out of volume III, "Dynamics." This development proceeds along two lines: Supplementary investigations to different parts of the book; and the direct redactional work. A short report concerning the progress along these two lines and some remarks in connection with practical consequences of our work are here given.

SUPPLEMENTARY INVESTIGATIONS

Dr. Petterssen has made a step forward in the theory initiated by Dr. Bergeron on the formation of atmospheric fronts. When the subject is treated completely, one must take into consideration simultaneously the field of motion and the field of that property (for instance, temperature) which is to be investigated. As long as both fields are linear, no actual front formation takes place; therefore at least one of the fields must be supposed to be not-linear. Dr. Petterssen takes cognizance of this, and deduces results which will be useful in practical weather forecasting. This, and the general review which Dr. Petterssen gives of the singularities which can occur in the linear field, will be incorporated in the new edition of "Kinematics."

Dr. Godske has sent to press (Geofysiske Publikationer, Oslo) a paper: "A Simplified Treatment of Some Fluid Oscillations." As all atmospheric disturbances, even those developing into cyclones, must start as some kind of small oscillations or waves, it is very important to arrive at easy methods of dealing mathematically with this class of motions. In cases in which it can be applied, the method developed by Dr. Godske represents a very effective simplification of the much more laborious "classical" methods used in our work "Hydrodynamique Physique" (see Year Books Nos. 31 and 32).

Professor Solberg has continued his theoretical investigations on wave-motions on a rotating earth. The aim of the investigations, which have been referred to in the last two Year Books, is to improve the Laplacean theory of oceanic and atmospheric tides, and to develop a complete theory of cyclones as waves in the atmospheric surfaces of discontinuity. The mathematical theories are completed and Solberg has started the numerical calculation of his formulæ. The results hitherto obtained show that the Laplacean free oscillations give a good approximation to reality as long as the period is short, but as soon as the period approaches the critical value of 12 hours, the Laplacean theory ceases to be valid. And for still greater periods the motion becomes totally different from those expected from the Laplacean theory.

Professor J. Bjerknes has recently sent in for publication (Geofysiske Publikationer, Oslo) a paper: "Investigations of Selected European Cyclones by Means of Serial Ascents. Case 3: December 30-31, 1930." For the plan of these investigations see Year Book No. 29. The study has been continued with the participation of an increasing number of cooperating aerological observatories, the aim being to find, by real ascents in sufficient number, the true structure of typical cyclones. The results, in general, confirm what had been expected from the Polar Front Theory, but it is still too early to formulate final conclusions. "Case 4" was February 15-17, 1935, when 15 aerological observatories cooperated upon a telegraphic start signal from Bergen.

REDUCTIONAL WORK

Dr. Godske has drafted the rearranged edition of "Kinematics." Thanks to 25 years of experience, in which this volume has been in practical use, the content will be much richer and more useful. It will be impossible here to enter into details. An important addition is the above-mentioned work of Dr. Petterssen.

Dr. Godske has also drafted the general introductory part of volume III, "Dynamics." Much is taken directly from our recently published "Hydrodynamique Physique," but with concentration upon those principles which are directly useful in oceanography and meteorology.

REMARKS ON PRACTICAL CONSEQUENCES

The telegraphic Weather Chart is to the meteorologist what the telescope is to the astronomer or the microscope to the biologist; it is the instrument through which he observes the phenomenon that he is studying. And as every step in the construction of the telescope or microscope advances astronomy or biology, so every improvement of the telegraphic weather service advances both practical forecasting and scientific meteorology. But as weather telegraphy depends upon international conventions, reform is exceedingly difficult.

After the formation of the Forecasting Central at Bergen, Norway, in 1918, the Norwegian representatives in the international committees and commissions have worked energetically for improvements, and now that the "Bergen Methods" are more liberally introduced in the meteorological service of an increasing number of countries, this has much facilitated the system of weather telegraphy.

Director Hesselberg, who in former years worked under the grant from the Carnegie Institution, and Dr. Bergeron have been most active in these researches. Bergeron has elaborated a proposal to "Comments on the New Codes for Synoptic Weather Information Adopted in Copenhagen, 1929." The aim of these "Comments" is to get the greatest possible uniformity and avoid confusion and errors in the observing, coding, decoding and forecasting work.

NUTRITION

Mendel, L. B., and H. B. Vickery, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-33.)

Our investigations of the salt mixtures employed to supply the mineral elements in the diet of experimental animals have been continued and one phase of the work has been completed. Four commonly used salt mixtures have been studied, the Osborne and Mendel IV salts, McCollum's 185, Steenbock's 40, and Sure's modification of the Steenbock 32 salts, and their relative efficiency has been judged by the rate of change in weight during a selected period of active growth and by the composition of the bones. Earlier investigations had shown that inadequacies in total amounts or in relative proportions of the various constituents were more evident when the salt mixtures were used in quantities other than those ordinarily employed. Accordingly we have studied each mixture at several levels of intake: 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 10.0 and 15.0 per cent of the ration.

It has become increasingly evident to us that, in evaluating the efficiency of a salt mixture for bone production, the rate of growth must be carefully considered. We strive for uniformity in this respect, and attain it to a high degree, but it is nevertheless true that all rats do not respond in exactly the same way even under identical treatment. For example, of the ten rats that received a diet containing 3 per cent Osborne and Mendel's salt mixture, one

TABLE A

Salt mixture in 100 grams diet		Gain per day	Food intake	Total cal- cium intake	Bone ash
	<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>per cent</i>
Osborne-Mendel....	3	6.6	281	1.06	56.1
		4.5	350	1.29	59.5
	4	6.4	307	1.49	59.8
		4.2	352	1.70	62.4
		6.6	293	1.76	59.4
McCollum ...	5	5.0	307	1.84	60.2
		6.1	291	0.67	54.4
	3	4.2	356	0.82	56.5
		7.7	270	0.81	56.3
	4	4.2	351	1.05	60.0
Steenbock.....	5	5.6	285	1.05	60.1
		4.2	344	1.27	60.7
	3	6.4	296	0.72	52.9
		3.4	374	0.91	57.2
	4	5.2	287	0.91	59.5
Sure.....		4.0	346	1.09	60.2
	5	6.4	279	1.09	57.2
		4.4	298	1.16	60.6
	3	5.6	271	0.70	53.9
		3.5	376	0.98	59.3
	6.4	278	0.95	57.7	
	4	4.2	332	1.13	60.3
	5	5.8	312	1.31	58.0
		3.8	374	1.57	61.8

grew at the rate of 4.5 grams a day and another at the rate of 6.6 grams a day. The average for all animals in the group was 5.4 grams a day. The bone ash for the slowly growing rat was 59.5 per cent in contrast to 56.1 per cent for the other. The food records show that approximately 25 per cent more food was consumed by the animal which took the longer time to make the desired gain. In table A we have summarized data to illustrate how frequently this type of variation is found.

Bearing in mind that rapid growth *within a group* leads to the production of relatively low ash for that group, the four mixtures mentioned have been compared at the levels indicated above. Some of the data are summarized in table B. It will be seen that there is considerable variation in rate of

TABLE B

Salt mixture in 100 grams diet	Osborne-Mendel		McCullum		Steenbock		Sure	
	Gain per day	Bone ash	Gain per day	Bone ash	Gain per day	Bone ash	Gain per day	Bone ash
grams	grams	per cent	grams	per cent	grams	per cent	grams	per cent
1.....	3.6	46.5	2.7	46.2	3.0	46.3	3.0	46.6
2.....	5.8	51.8	4.5	50.1	4.0	50.1	4.8	50.4
4.....	5.2	60.8	5.2	57.9	4.5	58.3	4.1	57.7
5.....	5.4	60.2	4.8	60.3	5.4	58.7	4.7	59.9
10.....	5.8	61.1	4.4	61.7	4.1	61.4	3.4	62.4

growth and in proportion of bone ash. With 1 per cent salt mixture in the food, the percentage of bone ash produced is the same in all cases, but the rate of growth is quite different, being 2.7 grams a day for the McCullum salt mixture and 3.6 grams a day when the Osborne and Mendel salts are used. At the usual 4 per cent level, the growth rate is the same when either Osborne and Mendel or McCullum salts are used, namely, 5.2 grams a day, but the bone ash is quite different, being 60.8 per cent with the former salt mixture and 57.9 with the latter. As judged by our criteria and aside from the question of which mixture may be more suitable, the four salt mixtures are clearly not interchangeable at any of the levels studied.

We have shown in an earlier report that calcium is a limiting factor in bone formation when the inorganic constituents are supplied in suboptimal amounts; that this is true of each of the four salt mixtures is shown in table C. In all cases there was an increase in the rate of growth and in the amount of bone ash produced when the calcium intake was increased; this was true in spite of the fact that the other inorganic constituents were supplied in relatively small amounts. These results suggested that it should be possible to construct a new salt mixture that would contain a larger proportion of calcium without increase in the other constituents. Such a salt mixture could be used at a level considerably below the customary 4 per cent, and our investigations are at present centered upon its preparation.

In previous reports we have referred to the rapid growth induced by the use of complex rations high in protein and in accessory food substances.

For a number of years our stock colony has been maintained on such a ration, which is similar to that devised by Professors A. H. Smith and W. E. Anderson in connection with their study of the effect of mating interval on reproduction. During this time, we have observed a marked increase in rate of growth, particularly during the first 100 days of life, and the reproductive performance has been improved. Recently we have compared the behavior of the animals of our stock colony as it is today with its performance in the

TABLE C

Salt mixture in 100 grams diet		Additional calcium per 100 grams diet	Daily gain	Ash of dry fat— fice femurs
	<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>per cent</i>
Osborne-Mendel	1	0 00	3 6	46 5
	1	0 43	5 8	59 5
McCullum	1	0 00	2 7	46 2
	1	0 46	5 8	58 5
Steenbock	1	0 00	3 0	46 3
	1	0 46	5 6	57 7
Sure	1	0 00	3 0	46 6
	1	0 45	5 0	58 9

early years of our studies, when other stock rations were used. As is well known, the colony has been maintained for twenty-five years without accessions from elsewhere. Our records show that there was a slow increase in growth rate from 1912 to 1931, undoubtedly due to careful selection of animals for breeding, as there was no essential change in the stock ration during that time. With the adoption of a new regimen in 1931, however, there was a marked increase in growth rate and in reproductive performance, and this has been maintained through succeeding generations. A report of this study is in press.

As a further check upon the efficiency of our stock ration, we have undertaken an investigation of the effect of pregnancy and lactation on the mineral matter in the bones. Preliminary data indicate that there is a significant decrease in total ash of the bones as the result of one pregnancy and lactation, but the loss is not sufficient to constitute a serious drain on the skeletal system.

In 1916 Osborne and Mendel showed that, when a ration containing zein as the only protein was supplemented by the addition of tryptophane, rats ceased to lose weight and were maintained over long periods of time; if lysine was supplied in addition, growth resulted. The rations used at that time contained considerable protein free milk, which doubtless furnished several unknown factors. We have thought it desirable, therefore, to repeat this experiment, using the modern type of diet prepared from purified foodstuffs, in which the unknown factors are much reduced. We have first duplicated the original experiment in order to ascertain the type of response obtained with the rapidly growing animals of our colony as it is today. Preliminary experiments indicate that the results are parallel to those of Osborne and

Mendel. We hope to be able to report soon the results of an attempt to obtain the same response with the 1935 type of diet.

In collaboration with Dr. Leonard G. Rowntree of the Philadelphia Institute for Medical Research, we are studying the effect on the *animals of our colony* of the daily injection of thymus extract. The extract is furnished through the courtesy of Dr. Rowntree. The work has not yet progressed to the point where we should expect to observe the striking acceleration in development he has reported. We have, however, noted that young rats, nursed by mothers receiving the extract, tend to increase in weight more rapidly than our stock animals.

Professors A. H. Smith and W. E. Anderson have continued the investigation of the reproduction of the albino rat referred to in previous reports. At the present time breeding operations of the first six generations have been concluded. With reference to influence of the interval between matings and reproductive performance, the summary of the data for the sixth generation indicates that, in three out of four experimental groups, there has been a definite improvement in the percentage of fertile matings over any of the previous periods of observations. These results represent a reversal of the experience recorded in last year's report. Furthermore, with respect to the average percentage weaned, there has occurred in three of the experimental groups an improved record in the sixth generation over that of the immediately preceding generations. This currently enhanced breeding performance is regarded as an evidence of an expected biological variation rather than as an actual improvement brought about either by selection or by diet. Attention was directed last year to the definite trend toward lower weaning weights in all groups in the fourth generation. In three of the experimental groups, the data of the additional generations indicate an unmistakable *increase* in body-weight at weaning. A preliminary report of this investigation was made to the Division of Biological Chemistry of the American Chemical Society, in New York, April 1935.

Our studies of the vitamin B complex, conducted in collaboration with Dr. R. J. Block, have been continued. Previous observations that the cruder vitamin B₁ and B₂ concentrates (Carnegie Institution Year Books Nos. 32 and 33) contain an additional substance necessary for growth and well-being of rats have been extended and a summary of our findings in regard to what appears to be a third essential factor in a vitamin B₁ concentrate prepared from rice polishings is ready for publication.

The chemical work during the past year has consisted of two main groups of investigations, the study of methods of plant analysis, and the application of these methods to the study of plant metabolism. We have long been convinced that chemical methods, to be really useful for the purpose for which they are employed, must be carefully adapted to the specific plant tissue under investigation; and before the results can be accepted as representing even an approximation to truth, it must be shown that the influences of sampling errors, of interfering substances, and of the mode of preparing the tissue for analysis, have all been duly considered and allowed for. The several methods for the determination of various forms of nitrogen, of carbo-

hydrates, and of the organic acids that we have studied in recent years have all been closely examined from these points of view.

Dr. G. W. Pucher of the Connecticut Agricultural Experiment Station staff attached to our laboratory has spent much time in the past year on the improvement of methods for the determination of ammonia and amide nitrogen in plant tissues. An accurate estimate of the so-called "preformed" ammonia of a tissue is essential, inasmuch as the quantity of amide nitrogen present is calculated from the increase in the ammonia nitrogen after hydrolysis under suitable conditions. Although the actual quantity of ammonia found in the tissues of many plants is usually small both relatively and absolutely, it is a metabolite of great significance, the proportion present being very sensitive to the conditions under which the plant has been grown.

It has been shown that the preformed ammonia of tissue can best be estimated by vacuum distillation with a reagent that consists of the correct quantities of a suitably chosen phosphate buffer and of a 5 per cent solution of borax in 0.5 N sodium hydroxide. The ammonia is trapped in dilute acid, the mixture is Nesslerized and the color is read at the spectrophotometer. Under these conditions the hydrolysis of the unstable amide glutamine, which is frequently found in plant tissues, is negligible, asparagine is not hydrolyzed at all, and none of the other plant constituents with which we are familiar gives off ammonia in appreciable quantities. The total amide nitrogen is calculated from the quantity of ammonia nitrogen found by distillation in the same manner after the tissue or extract has been heated for 3 hours at 100°C. with N sulfuric acid. An extensive survey of the range of applicability and of the limits of reproducibility and of accuracy of these methods has been made.

A large part of the amide nitrogen of the tissues of certain plants (tomato, beets, etc.) is due to the presence of glutamine. Several years ago Chibnall and Westall developed a method to estimate glutamine which depends on the observation that the amide group is completely hydrolyzed when the substance is heated at 100° in buffered solution either at pH 4 or pH 8 for 3 hours. Detailed study of this hydrolysis showed that better results were obtained if the buffer were so chosen as to give a final reaction of pH 6.5; under these conditions, asparagine and other substances commonly present in plant tissues are but little affected. We have accordingly undertaken a collaborative study of the problem of glutamine determination with Professor Chibnall and Dr. Westall of Imperial College, London, England, the results of which will be published in the near future. The revised method has been found extremely useful in the studies of glutamine metabolism referred to below.

The methods for the determination of total organic acidity, citric acid, and malic acid referred to in last year's report have proved of the greatest value in our investigations of organic acid metabolism. A further development of the citric acid method, made during the past year by Dr. Pucher with the collaboration of Dr. Caroline Sherman of the Department of Physiological Chemistry of Yale University, has rendered it possible to determine citric acid in quantities as small as 0.1 mg. in blood and urine. The procedure

consists in oxidizing the sample with potassium permanganate in the presence of potassium bromide, extracting the pentabromoacetone produced with petroleum ether, and treating the extract with sodium sulfide. The color of the aqueous phase is proportional to the quantity of citric acid taken, and can be read in the Pulfrich spectrophotometer with great accuracy. The method is approximately ten times as sensitive as the titration of the bromide we described last year. This refinement greatly increases the scope of application of the citric acid method: for purposes of plant analysis, where samples of adequate size may usually be obtained, the earlier titration technique is probably superior in accuracy, but cases have already arisen in which the desirability of the smaller scale method has been apparent. Dr. Sherman has applied the new modification to the study of the citric acid metabolism of animals; her results are being prepared for publication.

It has been found possible to determine the starch content of dried plant tissue by taking advantage of the fact that the familiar blue compound of iodine and starch is exceedingly insoluble in an acid aqueous solution that contains the correct proportion of inorganic salts. The dry tissue is prepared for analysis by being thoroughly extracted with alcohol; it is then ground to an exceedingly fine powder in a special glass ball-mill, and the starch is extracted either by hot concentrated calcium chloride solution or by cold 21 per cent hydrochloric acid. The extract is brought to a faintly acid reaction, and the starch is precipitated by the addition of iodine-potassium iodide reagent. The precipitate is subsequently decomposed by dilute alcoholic alkali which removes iodine and leaves the starch as an insoluble white powder. This is dissolved in hot water, is cooled and acidified with acetic acid, and the starch iodide compound is again formed by the addition of a mixture of potassium iodide and iodate. Under these conditions the blue substance remains in solution, and the quantity present can be estimated by reading the light transmission in the Pulfrich spectrophotometer against a suitable compensatory solution. A detailed description of this method will be published shortly.

The preliminary work on a method to determine the purine nitrogen of plant tissues has been completed and, when the final details have been established, we hope to be in a position to learn something of the purine metabolism of plants, a field in which but little information is available. The wide-spread occurrence of adenine in plants indicates the great desirability of this.

The development of methods to determine the chief organic acids in the plant tissues with which we are mainly concerned has now made it possible to undertake experiments upon the relationship of organic acid metabolism to the metabolism of other major constituents of the tissues. Determinations recently made upon leaves of the tobacco plant that had been cultured for 300 hours in the dark on distilled water¹ showed that the major changes that occurred were a marked diminution in the quantity of malic acid (from 177 to 47 milliequivalents per 1000 grams of fresh leaf) and an almost exactly equivalent increase in citric acid (from 23 to 176 milliequivalents). The

¹ The details of the preparation of this experimental material, together with a discussion of the effects of water culture upon the metabolism of nitrogen, are to be found in Carnegie Institution of Washington Publication No. 445 (1933).

curves that express the data are practically straight lines and are symmetrically disposed to each other. The oxalic acid remained constant in amount, as did the sum of the malic and citric acids. The total organic acidity varied more or less from sample to sample, but did not change materially throughout the period of culture.

There is little or no correlation between the variations in citric and malic acids and the variations in either carbohydrates or in nitrogenous constituents. The data as they stand suggest the possibility of a conversion of malic to citric acid, either direct or indirect, but this attractive hypothesis will require much further study before it can be regarded as established. We are inclined to regard the constancy in total acidity as an expression of the fact that, in this series of samples, the total inorganic base present did not change; we have much evidence that points to a close relationship between the total organic acids in the tobacco leaf and the basic ash constituents.

Our investigations of the alkaloids of the tobacco plant have progressed slowly, but final decision regarding the identity of several of the substances found to accompany nicotine in the fresh leaf must await the results of more detailed analysis now in progress. The separation of the individual substances in a state of purity has proven to be unexpectedly difficult because of their close similarity in chemical properties. We are practically satisfied that anabesine, reported as a tobacco constituent by Orichov, does not occur in Connecticut shade-grown tobacco. A substance that closely resembles the nor nicotine described by Ehrenstein is present, and it is the positive identification of this substance that is delaying the investigation.

Dr. H. E. Clark, a National Research Fellow, who has spent the past two years as a guest in our laboratory, has been of material assistance in our studies of glutamine. A method to prepare this extremely rare substance in quantity from the root of the common beet has been developed, and a description published. In the course of this work, we observed that the glutamine content of beet-root tissue may be very materially increased by applications of ammonium sulfate to the soil in which the plant is grown. There is an obvious relationship between this observation and that made last year upon the enrichment of tobacco leaf tissue in amide nitrogen after long-continued water culture had brought about a considerable degree of decomposition of the protein with its attendant production of ammonia *within* the cells.

The presence of glutamine in the unripe fruit of the tomato plant was first detected by Stieger in 1913. During the past year it has been found that this plant, when grown in culture with ammonium ion as source of nitrogen, becomes extraordinarily enriched in glutamine, the stems in particular appearing to function as storage organs. The identity of the amide was established by isolation, and a report of the work has been published.

Dr. Clark has also compared the composition of tomato plants cultured with ammonium ion as source of nitrogen, with similar plants cultured on nitrate ion. Marked differences were found in the quantity of amide nitrogen and its distribution in the several parts of the plant. Perhaps the most striking result of these experiments was, however, the fundamental difference in the proportion of oxalic, malic and citric acids in the two series. Calculated as per cent of the dry weight, the plants grown on nitrate contained

twenty times as much of these acids in the leaves and eight times as much in the stems as did the plants grown on ammonium. A full analysis of Dr. Clark's voluminous data is being prepared for publication.

We referred last year to the data that have been collected on the composition of the tobacco plant at various times during the growth period. This material has now been assembled and is in process of publication as a Station Bulletin. Curves which show the rate of accumulation of fresh and dry weight, of organic and inorganic solids both soluble and insoluble, of the carbohydrates, organic acids, and of many of the forms of nitrogen have been drawn, and an interesting picture is presented of the slowly accelerating growth during the first few weeks, the enormously rapid growth just preceding flowering, and of the translocations and transformations that occur during the development of the seed-pods. Particular interest attaches to the results of the examination of the organic acids, inasmuch as, for the first time, it has been possible to obtain accurate and trustworthy data for malic and citric acids for a single species throughout a whole season.

The growth of the plant as a whole can be roughly divided into three periods. The first is the period of 3 or 4 weeks in which the seedling established itself in the soil, but increased little in weight. The dry matter, organic acids, ash, carbohydrates and nitrogen in all forms increased in absolute quantity per plant, and the relative distribution of the individual organic acids, and of forms of carbohydrate and of nitrogen underwent considerable changes. During the ensuing period of rapid growth, organic and inorganic substances accumulated in the plant with surprising speed, but the alterations in relative proportions between the different constituents were less striking. The ratios between the individual organic acids remained remarkably constant, the proportion of fermentable carbohydrate in the leaves dropped temporarily during the time of most rapid growth, but soon recovered its earlier level, the proportion in the stem steadily increased. The relative proportions of the more active nitrogenous metabolites, *i.e.* the nitrate, ammonia, and amide nitrogen underwent material fluctuations, but, in general, nitrate in the leaf diminished, that in the stem increased.

In the final period, that of reproduction, the leaves decreased both in fresh and dry weight doubtless due to translocation to the fruit. The stems remained constant in fresh weight, but increased in dry weight, the organic acids and ash of both leaves and stems increased in absolute amount per plant, but remained steady in relative proportions. The nitrate nitrogen diminished sharply, doubtless due to exhaustion of the store in the soil, and the nicotine in the leaves increased, that of the stems remaining constant; the amides and ammonia in general decreased. The most striking feature was, of course, the rapid translocation of organic substances to the developing seed-pods in which large quantities of fat and protein accumulated.

The significant results obtained two years ago in our investigation of the katabolism of leaves in water culture have stimulated us to extend experimentation of this type. Accordingly, we have repeated the work on water culture as a control, and have in addition cultured leaves on a dilute solution of glucose and on a solution that provided nitrogen as ammonium ion. Duplicate cultures were carried out in light and in dark. The technique of

dealing with the samples has been very materially improved, and we are now engaged in the analytical work. We hope to arrive at a better understanding of the metabolic relationships of the organic acids and also to reach more definite conclusions with respect to the metabolism of the amides.

During the past few years several pieces of special apparatus have been developed; one of these, a stillhead for the rapid concentration of solutions has proved to be exceptionally valuable and a description of it has been published.

We have been fortunate this past two years in having Dr. H. E. Clark, a National Research Council Fellow, with us. He has been of the greatest assistance owing to his splendid training in the fundamentals of plant physiology. The scope of his activities is briefly indicated above. During the coming year we expect to have Dr. J. Melville, a Commonwealth Fund Fellow, with us. He has been trained in Professor Chibnall's laboratory, and will bring to us an expert knowledge of plant physiology and of organic chemistry.

The following have served as assistants in the work: Alfred J. Wakeman, Ph. D.; Charles S. Leavenworth, Ph. B.; Rebecca B. Hubbell, Ph.D.; Laurence S. Nolan, technician; Luva Francis, secretary.

Sherman, H. C., Columbia University, New York, New York. *Relation of food to length of life.* (For previous reports see Year Books Nos. 32 and 33.)

Those aspects of this research which are merged with Dr. F. G. Benedict's investigation of the physiology of old age are, or in due time will be, reported by him. The extension of his investigation into collaborative work with animals of our rat colony at Columbia University began soon after the grant from the Carnegie Corporation of New York had become available through the Carnegie Institution of Washington in 1933. At first, the elderly animals available for this purpose were only those afforded by previous investigations, but during the past year animals born in 1933 and designed from the beginning for the purposes of this research have, in constantly increasing numbers, reached ages qualifying them for Dr. Benedict's experiments, and have, therefore, constituted an increased and increasing proportion of the subjects of his experiments in the Columbia laboratory.

In order to avoid duplication of anything contained in Dr. Benedict's report, what follows is confined to those aspects of the work at Columbia University which were contemplated in our original application for financial aid and which have been treated in the past two Year Books as a distinct project.

The work is being continued in accordance with the plan outlined in the reports of the past two years. This plan includes three lines of experimentation: (1) To ascertain more nearly the precise chemical factors concerned in the nutritional improvement of health and longevity which we had found to result from a quantitative readjustment of the natural food materials composing an already adequate dietary; (2) experiments to test further modification of the better of the two dietaries concerned in the previous comparison; (3) experimentation of the same general type but from the new

starting-point of a more diversified dietary made up in reasonable resemblance to the average American food supply.

The first of these three lines of experimentation was already in progress in January 1933 so that a sufficient number of these experimental animals have now completed their natural lives to enable us to formulate findings on certain of the points under investigation.

Thus we are now able to report that the previously recorded superiority of our Diet B to our Diet A (although Diet A is "adequate" in the accepted sense of this term) is due partly but not exclusively to the higher calcium content of Diet B. In the experiments thus far completed, and described in a paper now in press, 54 males and 77 females have completed their life cycles on Diet A in direct and carefully controlled comparison with 49 males and 72 females whose diet differed only in that its calcium content was increased. That Diet A (Laboratory No. 16), with its calcium content of 0.2 per cent of its dry substance, is an adequate diet is rather strikingly demonstrated by the fact that rat families in our colony are still thriving in the 37th generation upon this diet alone; yet its modification by enrichment of its calcium content to 0.35 per cent of its dry substance (Diet 162) resulted in nutritional superiority as manifested in the rate and efficiency of growth, in the adult vitality, and in the length of life.

In view of recent warnings that maximal growth may not always be conducive to optimal vitality and longevity, it is of special significance that in these well-controlled experiments comparing Diets 16 and 162 (alike in other respects but differing in calcium content) the diet of more liberal calcium content increased *both* the rate of growth *and* the adult vitality and length of life. This is also true of the previously recorded comparison of our diets A and B, where the increase of calcium intake was the same but was accompanied by enrichment in some other chemical factors at the same time.

We have endeavored to discriminate carefully between differences in growth which are due to differences in diet and, on the other hand, those which are due to individual variation, *i.e.* such as appear between individuals of the same age, sex, strain and nutritional history. And, in comparing rate of growth with subsequent adult vitality and length of life, we have considered separately the growth-rates of two periods in the lives of our experimental animals, namely, (1) from conception until 28 days after birth, and (2) during the fifth to eighth weeks, inclusive, of the life of the rat. It is found that, whether the rate of growth be considered in terms of the body-weight at the age of four weeks or the gain in weight during the following four weeks in the case of the young rat (approximately analogous, respectively, to the completion of infancy and to the period of childhood in human life) the differences in rate of growth and in length of life among the individuals of the same sex on the same diet were independent of each other. That is, slower or more rapid growth as an *individual characteristic* does not measurably predispose to a longer or shorter life, at least under such normal conditions of nutrition as those with which we are here concerned. This finding may be of considerable intrinsic interest; and is certainly significant as clearing the way for further study and more rigorous and conclusive interpretation of the relations of food to evidences of nutritional well-being at different stages of

the life cycle as well as to the length of life itself. A short paper on this phase of the work has been published in the Proceedings of the National Academy of Sciences.

Thus the present investigation, while designated for the sake of conciseness as a research upon the relation of food to length of life, might perhaps be more adequately described as an exploration of the area which lies between the merely adequate and the optimal in nutrition, the relative nutritional welfare being judged not by any one criterion but by comprehensive and critical study of the several criteria afforded by the different stages of the life cycle.

We find, then, that the improvement of normal nutrition which we had induced by changing the proportions of foods in an already adequate diet is due in a significant degree, but not solely, to the enrichment of the calcium intake. We are experimenting further upon the effects of enrichment of intake of certain other chemical factors.

In the second of the three types of experiment above mentioned, we began early in 1933 the study of the addition of fresh meat and a fresh vegetable to the better of the two wheat-and-milk mixtures employed in the main series of our previous experiments. The addition of these foods has apparently induced a further increase in the rate of growth with slightly earlier maturity and larger offspring but has not appreciably reduced the death rates of middle age. Both because of limitations of laboratory space and in order to avoid any danger of a distortion of the data by seasonal influence, the starting of this series of experiments was distributed over the year 1933. These animals are, therefore, now from one and one-half to two and one-half years old, so that probably somewhat over a year must elapse before all of them will have completed their natural lives.

In the third type of experiment a new starting-point was sought in a mixture of a larger number of food materials so chosen in variety and relative proportions as to typify a usual and adequate but presumably not optimal American family food supply. This food mixture contained: Dried lean beef, 10; dried potato, 9; dried orange juice, 4; dried whole milk, 8; lard, 7; ground whole meat, 6; white flour, 40; sugar, 12; butter fat, 4 per cent. This had an energy value of 4.4 calories per gram and showed on analysis 16.7 per cent protein, 14.5 per cent fat, 0.19 per cent phosphorus, and 0.094 per cent calcium, or 0.021 gram calcium per 100 calories. The diet was thus of lower calcium content than is usually recommended for the feeding of laboratory animals, but not lower than is frequently met with in human food supplies. The animals received an adequate allowance of vitamin D in the form of viosterol. As briefly noted in last year's report, the rat families receiving this diet failed to produce a third generation and calcium deficiency was suspected. Analysis of several representative members of the second generation at the adult age of one year showed them to have a slightly subnormal content of body calcium, whether calculated as the absolute amount contained in the body, or in percentage of the fresh weight, or of the dry weight, or of the dry fat-free body substance. Moreover, the bones contained a slightly smaller proportion of the total body calcium than in animals of the same age whose calcium intake had been more liberal. Two papers dealing with this

phase of the work are now in press. New experiments have now been started, with some of the food materials shifted to what are presumably more favorable proportions corresponding with the moderate improvement of average American food habit under the influence of the newer knowledge of nutrition; and with the addition of calcium to correspond with that of an average drinking-water supply, inasmuch as the laboratory animals are given distilled water to drink in order that their mineral intake shall be accurately revealed through the records of their food consumption. These new experiments should serve both to supplement and further clarify the findings just mentioned and as a base-line for such further explorations in this particular direction as future conditions may permit.

It is a pleasure to make grateful acknowledgment of the cordial counsel of Dr. F. G. Benedict and of the highly efficient collaboration of all those immediate colleagues who have aided these investigations, whether as research assistants or as volunteers.

Williams, R. R., and Walter H. Eddy, Teachers College, Columbia University, New York, N. Y. *Physiological properties of the vitamins.* (For previous reports see Year Books Nos. 27-33.)

The investigation of vitamin B₁ was continued during 1934 with the aid of funds granted by the Carnegie Corporation of New York through the Carnegie Institution of Washington.

In our last previous report, evidence was presented as to the purity and physiological action of the crystalline product isolated in 1933. The composition indicated the empirical formula $C_{12}H_{18}N_4O\dot{S}Cl_2$, thus paving the way for a study of its structure.

In sodium sulfite solution at pH 5 the vitamin is split nearly, if not quite quantitatively, at room-temperature in the course of 24 to 48 hours into two products analyzing for the compositions $C_6H_7N_2SO_3$ and $C_6H_7NSO_3$, respectively.

The first is acidic in nature, its water solution having a pH of ca 5. It is very sparingly soluble in water but freely so in alkali or ammonia. It contains a sulfonic group as evidenced by the liberation of sulfur dioxide on fusion with alkali and of sulfuric acid on heating with water at 200°. The ultra-violet absorption of the acidic cleavage product exhibits a band heading at 248 and indications of a second band at about 270, the two absorption bands almost merging. By treatment with concentrated hydrochloric a second sulfonic acid is obtained having the composition $C_6H_7N_2SO_4$. Ammonia is thereby set free. Evidently the reaction consists of replacement of an amino group by hydroxyl. The resulting oxy sulfonic acid also liberates sulfur dioxide and sulfuric acid in a manner similar to the amino sulfonic acid from which it is derived. It shows ultra-violet absorption bands at 228 and 275. The absorptions of the amino and oxy sulfonic acids are respectively remarkably similar to those of 6 amino and 6 oxy pyrimidines of synthetic origin. Pyrimidines in which single amino and oxy groups occupy other than the 6 position (or 4) show absorptions which are in strong contrast to those of our sulfonic acids. On the basis of this and correlative chemical evidence, it has been concluded that the vitamin contains a 6 amino

pyrimidine grouping. Tentatively we regard the acidic cleavage product as 4-ethyl, 5 sulfo, 6 amino pyrimidines, but further evidence is required to establish the structural relationship of the sulfo and alkyl groups to one another and to the pyrimidine nucleus. Efforts to do this by replacement of the sulfonic group with some other group which is well known in association with pyrimidines have not as yet been successful on account of the occurrence of deep-seated degradations. Pyrimidine sulfonic acids are unknown.

The second product of the unique sulfite cleavage reaction above described is a base which is extracted with chloroform from the reaction mixture after rendering it alkaline. It is recovered in crystalline form as the hydrochloride. It has the characteristics of a tertiary base, forming a para nitrobenzoate by condensation on the oxygen of the molecule, the resulting product still exhibiting basic properties. On oxidation with dilute nitric acid, it yields the product $C_8H_8NSO_2$ identical with the acid previously described by Windaus,¹ as obtained directly from the vitamin by similar oxidation. By heating the basic cleavage product with concentrated hydrochloric acid a similar base is obtained of the composition C_8H_8NSCl . Evidently a hydroxyl group is replaced by non-ionic chlorine, as is also the case with the vitamin itself under similar treatment.²

The distinctive behavior of the sulfur in this basic cleavage product has been studied by the kind collaboration of Dr. H. T. Clarke. With his collaborators he found that while the vitamin liberates sulfur as lead sulfide relatively rapidly with alkaline plumbite, the basic cleavage product does so very slowly. Conversely the sulfur of the vitamin is resistant to bromine while that of the base is largely oxidized to sulfuric acid. The nitric acid oxidation product yielded lead sulfide with plumbite. These facts pointed to bivalent sulfur in both the base and its oxidation product but in a form peculiarly resistant to oxidation by nitric acid. This resistance to the action of nitric acid suggested to Dr. Clarke a thiazole nucleus which was presently confirmed in large measure by comparison of the ultra-violet absorption of the natural products with those of appropriate synthetic thiazole derivatives.

These observations cleared up several important features of structure but confronted us with difficulties as to the mode of union of the thiazole nucleus with the pyrimidine nucleus. It was clear from its resistance to hydrolytic cleavage that the sulfonic group of the acidic cleavage product was attached to carbon rather than nitrogen. We could not assume that the bond between the two nuclei is carbon to carbon, for this is inconsistent with the ease of splitting by sulfite. The oxygen atom of the thiazole structure was excluded as the point of its attachment to pyrimidine by the fact that the oxygen in the vitamin is replaceable by chlorine without splitting; the sulfur atom was likewise excluded by the evidence that the sulfur is bivalent both in the vitamin and in the split product, yet not in sulphydryl form in either. The nitrogen of the thiazole cleavage product was clearly tertiary and seemed therefore also to be excluded until Dr. Buchman suggested the happy idea of nitrogen in a quaternary state in the vitamin being converted by sulfite cleavage to a trivalent condition. This suggestion soon cleared up all these

¹ A. Windaus, *Z. physiol. Chem.*, vol. 288, 27, 1934.

² Carnegie Inst. Wash. Year Book No. 33, 299 (1934).

difficulties as well as those associated with the discrepancies in the properties of the sulfur of the vitamin as compared with that of its split product. It was soon found that thiazolium compounds in which the nitrogen is quaternary, whether these compounds were prepared from synthetic material or from the natural cleavage products, behaved in a manner similar to that of the vitamin with respect to liability of sulfur to alkaline plumbite, to alkali followed by nitroprusside and also to bromine. The quaternary character of one nitrogen in the vitamin was also confirmed by a potentiometric titration of its hydrochloride which revealed a basicity too great for a tertiary nitrogen. This titration also brought to light a distinctive behavior in that the monochloride of the vitamin required two moles of alkali to reach a definite endpoint, rather than one as would be expected. This unusual characteristic is also displayed by quaternary thiazoles of both natural and synthetic origin. It appears probable that it is associated with an opening of the thiazole ring in alkaline solution.¹

The structure of the complete vitamin molecule has been defined tentatively² and the identity of the basic cleavage product has since been fully confirmed by synthesis.

In addition to the foregoing chemical work, studies have been carried out on the effects of graduated doses of the vitamin on growing rats and full-grown pigeons. Rats on the widely used Sherman-Chase diet display a remarkable behavior when the vitamin intake is raised to 50 or 100 fold that which is necessary for prevention of polyneuritis. With increasing size of dose they grow at increasing rates and on the larger doses attain a size 10 to 20 per cent greater than would normally be expected in this strain of animals on artificial diets. Reproduction appears to be subnormal, both as to the number of litters and as to the viability of the young. Second-generation young have shown similar high growth-rates and have attained large size but have produced only one litter of viable young.

This failure of reproduction, however, appears not to be connected with the amount of vitamin B₁ but to some defect of the Sherman-Chase diet which is not remedied by addenda of vitamin E or other known vitamins. Animals fed on a diet composed of one-third whole milk and two-thirds whole wheat reproduce quite normally, even when large addenda of vitamin B₁ are given. However, on this diet no effect of large amounts of B₁ can be noted either with respect to growth-rate or ultimate size. One is led to surmise the presence of some growth inhibitor or growth regulator in the latter diet, but further experiments will be necessary to reach a conclusion.

An interesting outgrowth of the work done under the Carnegie grant was in part suggested by the rat experiments. Since it was possible to enhance growth-rate beyond "normal" by administering large daily doses of vitamin B₁, it appeared that the vitamin was catalysing the metabolism of food. Further, since the diet consisted predominantly of carbohydrate, it seemed wholly probable that carbohydrate metabolism was promoted. We therefore sought an opportunity to have the effect of the vitamin tested on diabetes. Dr. M. G. Vorhaus has conducted such a trial. The results so far

¹ Mills, Clark and Aeschlimann, *Jour. Chem. Soc.*, vol. 123, 2353, 1923.

² *Jour. Amer. Chem. Soc.*, vol. 57, 229, 1935.

obtained are of a preliminary nature but indicate a marked favorable influence in a substantial proportion of diabetics. Dr. Vorhaus also reports favorable results in the treatment of neuritis.

The foregoing work required the isolation of about 12 grams of the vitamin in crystalline form. This exacting and tedious work was performed largely by Dr. John C. Keresztesy aided by Mr. R. E. Waterman and Dr. Samuel Gurin. The necessary bioassays in this connection as well as the performance of the rat experiments were done by Miss Marion Ammeiman. We are also much indebted to Dr. H. T. Clarke, not only for his valuable original contributions but for many laboratory facilities, especially the microanalytical services of Mr. W. J. Saschek. Dr. E. R. Buchman was conspicuous in the work of preparing and identifying degradation products of the vitamin. Mr. Waterman contributed in many phases of the work. Dr. Gurin collaborated with Dr. Clarke in the structural chemistry of the thiazole fraction. A very valuable aid in both the pyrimidine and thiazole phases was rendered by Mr. A. E. Ruehle, who secured the ultra-violet absorption and potentiometric titration data. It is a matter of keenest regret that this happy and effective alliance has largely been broken up by the progress of events.

PALÆONTOLOGY AND GEOLOGY

Merriam, John C., and Associates. *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-33.)

Researches concerning problems touching the history of life and the story of the earth have been limited to a comparatively small group of projects relating to certain questions of special importance at this stage in development of the earth sciences.

Following studies recently initiated on the two major divisions of the geological section found at the bottom of the series of strata in the Grand Canyon, researches have been continued by Dr. Ian Campbell and Dr. John H. Maxson on the Archean, or the lowest division of the Grand Canyon, and by Dr. N. E. A. Hinds on the Algonkian, representing the next to the lowest division. Special reports on these regions in the Year Book give detailed accounts of the investigations. It is important to note that these studies represent two of the most important approaches to the earliest known stages in geological history of the earth. As has been indicated in earlier reports, the work of Campbell and Maxson has shown a great thickness of rocks in the Archean, a high degree of crustal movement, and a history which will have important place in study of this earliest known division of geological time.

The contribution by Dr. Hinds on study of the Algonkian covers a wide field of research with careful investigation of details regarding the character of the sediments, the nature of the conditions under which these formations were accumulated, and the history of crustal movements which have affected these deposits.

Investigations carried out by Dr. Buwalda, Dr. Stock, and others on formations of the Cenozoic or the last era in the geological sequence of western North America have great importance in that they bring close to a final statement the history of a region which has been subjected to exceptional influences in crustal movement, igneous activity, and sedimentary accumulation.

The studies of Dr. Ralph W. Chaney in the field of palæobotany, presented in the report of the Division of Plant Biology, have from another angle not only covered the history of floras in western North America, but they have contributed as well a large amount of information relative to climatic changes, crustal movements, and varying phases of distribution and migration represented in the story of plant life on the western hemisphere.

The work of Dr. Chester Stock and Dr. Remington Kellogg in the field of mammalian palæontology has given us some of our most interesting contributions relative to land faunas, studied by Dr. Stock, and to the evolution of marine mammals, contributed by Dr. Kellogg.

In research on early man, work by Dr. Edgar B. Howard has made possible the bringing together of extremely valuable data concerning some of the most important occurrences of human remains and the associated

faunas in western United States. The work done originally by Dr. Howard at Carlsbad Cave and extended by more comprehensive studies at Clovis, New Mexico, has given one of the most interesting chapters in early history of man in America. In the studies at Clovis Dr. Howard has been joined by Dr. Ernst Antevs, who has made an extremely valuable report on the nature of the deposits, the evidence of climatic changes which they furnish, and the age of the formations represented.

The studies of Dr. Paul MacClintock, associated with C. B. Schultz and A. G. Lugen, have again given an extremely interesting contribution to certain phases of physiography and geology of the regions in which early human remains occur.

The contribution of Dr. Chester Stock toward study of remains of higher animals associated with early man adds another important phase to this critical investigation.

In an entirely separate field, but related nevertheless in an intimate way to the work of students of early man in western North America, are the investigations of Dr. H. de Terra, of Yale University. Through the aid of the Carnegie Corporation of New York it has been possible for the Carnegie Institution to cooperate with Dr. de Terra and to help in furtherance of investigations which are supported also from other sources, especially by Yale University and the American Philosophical Society. Dr. de Terra's researches on the problem of early man in southern Asia touch a field of great significance in study of the beginnings of human history. There is no region of the world which seems at the moment to have greater importance in this study than the area covered by Dr. de Terra's work, and results of exceptional interest may be expected.

Investigations of Mr. Merriam have touched all of the problems discussed, and have extended also into a study of the means by which the data available from geological sections of the age of mammals in western North America may be brought together in a comprehensive review of formations, faunas, and their relations to each other in time.

Mr. Merriam has concerned himself also for some years with a study of the responsibility of science for the use and protection of exceptional phenomena represented in primitive natural areas which have unusual importance in the development of science, and in our understanding and appreciation of nature.

The contribution of science toward acquaintance with the natural world has in general been looked upon as not particularly significant so far as appreciation of nature is concerned. But when basic studies of great groups of features are undertaken, it becomes clear that science has in its power the possibility of contributing in a very real way, not merely to the understanding of the natural world, but to the appreciation also, even in the sense in which these values have been recognized by artist, poet, and philosopher.

It will always be instructive to study the impinging of new forces upon primitive nature. Experiments of this type will have great value, but the significance of such studies will depend, in considerable measure, upon knowledge of what nature does without influence of such factors.

Researches of Chester Stock

Survey of needed facts for and revision of the Correlation Paper has concentrated attention upon the Pliocene and Miocene history in western North America. Progress is being made in the completion of field and laboratory studies to the end that this portion of the paper may be published as soon as possible. The report by Dr. F. D. Bode on the *Fauna of the Merychippus Zone of the North Coalinga District, California*, and that by David Scharf on a *Miocene Mammalian Fauna from Sucker Creek, Oregon*, were published as Articles VI and VII, respectively, of Publication No. 453, Carnegie Institution.

Study of a late Pliocene fauna from the Coso Mountains of California has been in progress by Mr. John R. Schultz. A survey of the horses from this horizon has established more clearly than has heretofore been the case the relationships of the genus *Plesippus* and has led to a comprehensive review of all the types referred to this genus. The report by Schultz has been submitted to the Institution for publication. An important contribution to our knowledge of Pliocene rodents has been completed by Mr. R. W. Wilson. This relates to a Pliocene rodent fauna from Smiths Valley, Nevada, and includes the description of significant forms not previously known in the phylogenetic history of the Geomyidæ and the Zapodidæ. This paper has also been submitted for publication to the Carnegie Institution.

QUATERNARY STUDIES

A joint report by Chester Stock and F. D. Bode on the geology and vertebrate palæontology of the late Quaternary near Clovis, New Mexico, has been submitted to the Academy of Natural Sciences of Philadelphia.

Dr. E. Raymond Hall of the Museum of Vertebrate Zoology, University of California, has completed a comprehensive review of the Pleistocene Mustelidæ of North America, an investigation of considerable value to all students of Quaternary faunas.

An important Quaternary assemblage of mammals and birds, collected by M. R. Harrington in Smith Creek Cave, eastern Nevada, is being studied by David Scharf, Dr. Hildegard Howard and Dr. Alden Miller. This promises to shed light on the history of late Quaternary life in a region bordering the western edge of the basin of Pleistocene Lake Bonneville.

In addition to a further study of the Pleistocene Camelidæ of western North America, with special reference to the Rancho La Brea collection, steps have been taken to review the vertebrate collection obtained many years ago in association with human remains in Pit 10 at Rancho La Brea. Re-study of this collection seems particularly desirable at this time, in the light of current Quaternary investigations, as offering opportunity to determine the constituency of a fauna which seems to date in time from a period between that of the typical Pleistocene assemblages of the asphalt and that of the Recent.

John L. Ridgway has prepared or supervised practically all of the illustrations included in the several palæontological reports. Mr. Ridgway has likewise completed a manuscript for a book on the preparation of illustrative

material as a guide particularly for authors. Mrs. Marie Mahon has continued to render noteworthy assistance in the preparation of research materials and in the typing of manuscripts.

Researches of Remington Kellogg

As regards the project for "A study of the evolutionary history of the cetaceans," attention was given principally to new material recently collected in the Eocene Ocala limestone (upper Jackson formation) of Georgia. This material extended the geographic range of archæocetes previously known to occur in the Gulf Coastal Plain. As mentioned in previous reports, the study of the Archæoceti has brought forth additional information regarding the general bodily construction of these marine mammals. Reconstructions of the skeletons of two of the North America archæocetes have been completed.

Search for cetaceans in the Miocene Calvert formation of Maryland has materially increased our knowledge of that fossil assemblage. The accumulating material is gradually filling the existing gaps in our knowledge of the skeletons of the cetaceans comprising that fauna.

Vertebræ belonging to an Eocene sirenian found in the basal portion of the Yagua formation in Burleson County, Texas, have been studied and a report dealing with this specimen is being prepared.

Illustrations for the reports completed and in progress have been prepared by Sydney Prentice.

Researches by J. P. Buwalda

A study of the physiographic history of the Yakima region, central Washington, pursued intermittently for brief periods through several years, was brought virtually to completion during the late summer of 1934 and most of the results were prepared for publication. The later chapters in the Tertiary history of this territory are ascertainable largely through the presence of a sedimentary formation—the Ellensburg—containing enough vertebrate fossil material to afford at least an approximate age determination, thus dating certain episodes.

In earlier accounts of the physiographic history, the extrusion of the Columbia basalts and the deposition of the overlying Ellensburg sediments were followed by gentle folding, producing a first generation of east-west anticlines and synclines on the sites of the present ridges and valleys. During Pliocene time these features were believed to have been completely effaced by erosion, yielding a wide-spread peneplane extending even over the Cascade Mountains to the west. In late Pliocene or Quaternary time, folding was resumed along the former axes and the present ridges and valleys came into being. The evidence for peneplanation and two cycles of erosion was believed to be (1) bevelling of the basalts on the higher parts of the anticlinal lava ridges, (2) smooth truncation of lava and sediments at Kelly Hollow, considered to be the type locality for the predicated Pliocene peneplane, and (3) supposed intrenched meanders of the Yakima River where it cuts Yakima Canyon across three anticlinal basaltic ridges between Yakima and Ellensburg.

In the present investigation it was found that in the Yakima region the basaltic anticlines are not bevelled but that all the basaltic slopes and crests are essentially stripped surfaces, which have been but little modified by erosion since the overlying much softer Ellensburg formation was removed. They are "dip slopes." In the valleys the unresistant sediments are bevelled, but this surface meets the steeper basaltic dip slopes at a sharp and conspicuous angle, indicating that the smooth surface on the Ellensburg beds is not part of a deformed peneplane. At Kelly Hollow, where basalt and sediments were thought to be truncated smoothly and indifferently, it was found that while the sediments are bevelled the basalt merely gives the appearance of having been cut across smoothly. In reality a minor structure in the lava brings about a sudden flattening of the upper flow and the presumed peneplane remnant is here also virtually a stripped surface. It is doubtful whether the sinuous portions of the Yakima River Canyon represent meanders at all, but if so, those original meanders could have existed as well on the final surface of aggradation of the Ellensburg formation as on a later peneplane cut across lavas and sediments.

The new view here advanced is therefore that the evidence heretofore offered for Pliocene peneplanation does not support that conclusion and reconciles as well with the hypothesis of a single as of a two-fold deformational episode. Instead of peneplanation during the Pliocene, the evidence points with at least equal consistency to a beginning of vigorous deformation in late Pliocene time, continuing even to the present day, with concurrent erosional degradation, resulting in the production of the existing central Washington landscape.

*Climate of the Southwest During the Late Wisconsin Glaciation, by
Ernst Antevs*

The only means, so far available, of dating finds of human remains and artifacts in the southern Great Plains area and in the Southwest of the United States is to correlate the deposits in which the remains and artifacts occur with the continental glaciations in the northern half of the continent. Such correlations can, it seems, be made only on the basis of the evolution of the climate. This study aims to augment the knowledge of the climatic evolution and especially to treat the relative rôles of temperature and precipitation. To this end the late Wisconsin glaciation line, *i.e.* the summit altitude necessary for the development of small glaciers, is being studied in the southern Rocky Mountains and in the Sierra Nevada.

The difference in altitude between the late Wisconsin glaciation line and the modern glaciation line, and the decline of the latter with drop in temperature, furnish a means to calculate the approximate late Wisconsin temperature. A fair idea of the precipitation conditions may be had by comparing the glaciation lines in the Rockies and in the Sierra Nevada and by studying the late glacial, or pluvial, water-levels in closed basins in relation to the mountain glaciations. Most promising among such basins is that of Estancia, south of Santa Fe. It is important that glaciation is favored by snowfall; rise of semi-desert lakes, by rains.

Thus, the Pluvial period and its manifestations in high lake-levels, lake beds, and erosion by the streams, can probably be approximately dated in relation to the climax of the mountain glaciation. The last extensive glaciation in the mountains may have culminated contemporaneously with, or slightly later than, the ice sheets west of Hudson Bay and the Great Lakes, i.e. roughly 25,000 years ago.

Most of the high ranges of the Rocky Mountains in the middle section of Colorado have been visited. The field work is still in progress. It appears that the glacial features which by previous students have been attributed to the younger of the two usually distinguished mountain glaciations represent two separate glacial ages, probably one early Wisconsin (= Iowan) and another Late Wisconsin. The latter was the less extensive and failed to occupy many cirques of the next previous glaciation.

*Investigation of the Geology of the Yuma-Folsom Sites in Western Nebraska,
by Paul MacClintock*

At the invitation of, and in conjunction with, the Nebraska State Museum and the Nebraska State Geological Survey, represented in the field by C. B. Schultz and A. L. Lugen, respectively, this investigation was undertaken. A grant from the Carnegie Institution of Washington made possible the field work. Study was made first of the stratigraphy of certain sites where Yuma-Folsom artifacts have been found, and second of the glacial history of White River where varved sediments were found. The varves appear to be younger than the alluvial deposits which contain hearths, burned bones, and Yuma-Folsom artifacts.

(1) *Bratt Camp*—Five miles east of the upper end of the North Dismal Creek, Hosker County, Nebraska. Mr. R. R. Langford took us to this site in the heart of the Sand Hills. Here wind and sheet erosion have laid bare, over an area $\frac{1}{8}$ by $\frac{1}{2}$ mile, an old peaty loessial soil in which Yuma-Folsom points are associated with the *Citellus* fauna.¹ Since the site might have been a depression among the sand hills, and hence post-sand in age, the stratigraphic evidence of age is inconclusive and the age must rest on the faunal association.

(2) *Nolan Blowout*—Ten miles west of Imperial, Chase County, Nebraska. Here sand, which is judged to be of late Pleistocene age by its soil profile, has been blown away to a depth of 10 to 15 feet exposing fossiliferous loess, 2 to 3 feet below which Yuma-Folsom points are found associated with the *Citellus* fauna. Stratigraphic evidence points to a pre-Wisconsin age for the artifacts.

(3) *Scottsbluff Bison Quarry, Scott County, Nebraska*—Below 12 to 15 feet of undisturbed fossiliferous loess of Peorian age, Yuma-Folsom points were found by Barbour and Schultz, associated with Bison of the *Citellus* fauna.

(4) *Cape Site, Greenwood Creek, Lincoln County, Nebraska*—This site proved to be inconclusive, for the deposit in which the artifact was found seems to be entirely post-Pleistocene and not part of the terrace in the main

¹ A. L. Lugen and C. B. Schultz, *The Geology and Mammalian Fauna of the Pleistocene of Nebraska*, Nebr. State Mus., Bull. 41, vol. 1, 320-393, 1934.

part of the valley. Rains in the Spring of 1935 undercut the bank and exposed 2½ feet of black leached soil at the base of the deposit commensurate with the soil on the terrace.

Varved sediments were found in the valley of White River and its tributaries near Crawford, Nebraska; near Interior, South Dakota, in the river's mid-course; and near Chamberlain, South Dakota; where the river joins the Missouri. While the details of the glacial history of White River and Missouri River are not completely known, Todd has shown that ice of the Dakota Lobe, of what is now known as the Mankato stage of Wisconsin glaciation, dammed the eastward-flowing rivers of the Dakotas, caused them to spill over and cut down the divides and thus establish the present course of the Missouri. The mechanism seems to be at hand to produce an ice-dammed lake in the White River valley in which varved sediments could have accumulated. But the spillway of such a lake now stands at between 1600 and 1800 feet elevation, whereas the varves at Interior are at 2340 feet and those near Crawford are at 3665 feet. Two possibilities are evident: The varves were deposited in local ponds, while the valley had its present elevation, and so have no significance in the present consideration; or were deposited in an ice-dammed lake while the western part of the region stood 2000 feet lower than now. In the present state of knowledge, varved sediments are considered diagnostic of ice-dammed lakes. If it be true that the varves in White River valley were deposited in a lake dammed by the Mankato advance of Wisconsin ice, we have (1) a dated and measured rise of the western Great Plains, and (2) a dated episode showing that at least some of the Yuma-Folsom artifacts are of Pleistocene age.

de Terra, H., Yale University, New Haven, Connecticut. *Studies of geology, palæontology, and archæology relating to the origin and evolution of man as it may be recorded in the Himalayan region of Asia.*

This expedition was organized by Dr. H. de Terra for a study of Early Man in Northern India. The research method employed was to be a multiple approach from the geological, palæontological and prehistorical angle. In 1932 Dr. de Terra and his associates of the Yale North Indian Expedition had found a number of new types of fossil anthropoid apes in the Siwalik formations and prehistoric artifacts in the overlying Pleistocene strata. These finds indicated that through further investigations Northern India would yield information concerning Early Man's evolution and of his Stone cultures in the Pleistocene. India, which has hitherto been much neglected in the modern search for ancient human cultures, should be regarded as a first-rate research field. The three premises so essential for any successful study in this field are a complete sequence of Tertiary and Pleistocene formations, a great wealth of fossil mammalian remains, including anthropoid apes, and an abundance of archæological sites and ancient traditions which prove the great antiquity of native cultures. All of these conditions are to be found in Northern India.

The realization of this plan called for cooperation with Indian institutions and such research bodies as have lately played a leading rôle in the field of prehistory, as for instance the Cenozoic Research Laboratory in

Peiping and Cambridge University. This latter institution became eventually represented in the expedition staff by Mr. T. T. Paterson, and the Cenozoic Research Laboratory by Dr. Teilhard de Chardin, whose services could be secured for a period of three to four months. In addition a palæontological collector of the Geological Survey of India was to be employed.

The plan received support of the Carnegie Corporation of New York by means of a grant to the Carnegie Institution of Washington. A fund was also provided by the American Philosophical Society. The expedition budget included the expenses for a palæontological collector and for Dr. Teilhard's field excursions. Mr. Paterson received grants from the Royal Society and from Cambridge University.

EXPEDITION'S FIRST RESULTS

The expedition leader and his Indian assistant, Mr. D. Sen of Calcutta University, entered the field in the middle of March. They began work in the Central Salt Range and continued throughout April in the neighboring Soan River Valley. Here they were eventually joined by Mr. Paterson. During May and June the collector, Mr. N. K. N. Aiyengar, and Mr. Sen collected in the Siwalik formations of Jammu and in the Eastern Salt Range. Since July 1st the expedition staff has been working in Kashmir.

In the field of palæontology, the expedition has secured a couple of hundred vertebrate fossils of Pliocene and early Pleistocene age. Among them are ten Primate remains, the majority of which belong to anthropoid forms allied to *Sivapithecus* and similar highly specialized types of hominid affinities. Early Pleistocene fossils were found at Tatrot in connection with eoliths of doubtful human origin.

The discovery of numerous Stone Age sites in the Punjab has resulted in a substantial collection of artifacts. Typologically there are represented pre-Chellean flakes from the Boulder Conglomerate of the so-called Upper Siwalik formation, a Chellean pebble culture belonging to an interval between two lake stages in the Potwar area; a Levallois industry, *in situ* and also rolled from younger Pleistocene gravels; an Upper Palæolithic flake industry from Chitta (Central Salt Range); and "Mesolithic" cores and flakes from various younger land-surfaces. In addition to such Old Stone Age cultures there were found isolated polished celts, polished stone tools either singly or in association with pottery as in the Sind Valley of Kashmir, where a "midden" was recently unearthed by Mr. Paterson. Fragmentary pottery in association with megaliths and with flakes and bone ornaments were found at several places in Kashmir.

Further investigation of caves and terraces in the Punjab is bound to yield more material, and a better understanding of stratigraphical sequences can be hoped for as soon as the Ice Age records in the neighboring Kashmir Mountains have been studied.

In this respect the expedition has secured definite results which prove a four-fold glaciation in the mountainous tract. The glacial cycle during the Pleistocene was here complicated by intermittent uplifts in the glaciated ranges. The first and second Interglacial phases witnessed strong uplifts

which evidently followed the lines of orogenic movements of mid-Tertiary origin. According to the position of the sectors investigated within the southern Himalayan orogen, the strength of glaciation changed in intensity. For instance, north of the Kashmir Valley, along the slope of the main Himalayan range, the first two glacial advances were stronger than the later two, whereas south of the valley the first advance must have been weaker than the second, owing to a lower elevation of the southernmost Himalayan range. The third ice advance was here, however, more powerful than in the northern tract on account of the steepening valley gradient which was brought about by the second interglacial uplift. The Pleistocene Kashmir lake lasted from the first until the second interglacial, the fluvio-glacial outwash of the second valley-glacier advance is found embedded in its silt and clay deposits. These have locally yielded remains of elephant, birds, fishes and fresh-water shells, and also a rich interglacial flora of which some 600 specimens have already been collected.

During the coming months the expedition members will travel in separate parties through the adjoining regions of Poonch, Jammu and the Punjab foothills and their next task will be to connect the Pleistocene events of Kashmir with those of the Plains. The palæontological collecting will continue in the same regions and concentrate on those localities where Primate remains can be expected.

Wieland, G. R., Yale University, New Haven, Connecticut. *Cycadeoid investigations.*

Special attention is asked to the reports in Year Books Nos. 31, 32 and 33, as these outline in brief not only the larger field of cycadeoid study, but the status of work within it and the methods and objects pursued. The order of study given has been closely adhered to, with the result that further and even extended publication on the petrified cycadeoids is within near view.

As far as can be discerned at present, a collateral study of cones in the conifers as a greater group, such as has been carried out in the case of the Cerro Cuadrado forest, proves singularly apropos to cycadeoid study. This emphasizes the need for the closest attention to the inflorescence in all its types, ancient and modern, if we are ever to gain any true or closer perspective of higher seed plant descent. It proves once more that stem and floral structures must be used together in the classification, wherever possible. Altogether striking is the fact now proven that heavy stemmed cycadeoids, fertile in all frond axillæ, were very widely distributed in all of Cretaceous time, being in evidence at the close of the Jura, and that the wood structure so nearly approached that of homoxylous angiosperms. No botanist should overlook the fact that there is within the relationship a series of small flowered forms with branching like that of magnolias. Moreover, here is a spiral insertion from which by the change over into leaf whirls, stem elongation and branching, "panicles" as complex even as those of the *catalpa*, might come into the view. Not yet is there direct evidence for this or any theory of dicot origin; but discussion is now greatly extended, and it is seen that the important field of cycadeoid study is no longer that of the heavy-stemmed forms

but concerns the imprints and casts as met primarily in India, in the Lias and Oölite of Mexico, and the many fine Rhætic localities of Chile and Argentina. Need it be remarked how recently European localities were made to yield Caytonia! Or that the Rhætic of Virginia and North Carolina has not been studied by chemical methods? Or that so far no collector has tried out the Dockum beds of Texas?

In bringing the heavy-stemmed cycadeoids into a completer view, the etching methods mentioned two years ago as of great help have been found more and more effective. In fact as it turns out, there is scarcely any petrified material which can not at some point of study be chemically treated, retouched, or both, to advantage. In the cycads or the varied fern and seed-fern types, even the rough saw-cuts may at once be made to yield all larger structural features, whatever the texture. Perhaps no more striking instance of the use of these methods may be cited than our serial thick-sections cut to bring into view the course of the frond and complementary peduncle traces in a free-flowering cycadeoid stem of a dark and carbonaceous texture. Such thick-sections of the largest convenient area are soon cut, and soon etched, affording clear photographs. By the thin-section method, because of the extreme thinness required by the texture, all this work would be long and laborious. But it is of course not inferred that polishing is of no use at all in the thick-sections.

In the chemistry of petrification, important facts are coming into view. It is now certain that we know how to begin in a replacement of vegetal structures by lime or silica, and that specially constructed containers or autoclaves allowing a fair comparison of the effects of temperatures and pressures on the several silicic acids in the presence of carbon dioxide and more or less lignitized or dehydrated woods will soon solve the replacement problem. For there is here not merely the single question of petrification whether from the scientific or even commercial side, but a whole series of facts of primary importance in geophysics to bring into reckoning. Twenty-four years ago F. W. Clarke said pointedly, "No one process can account for all the occurrences of amorphous or cryptocrystalline silica, and each locality must be studied in the light of its own evidence." It is seen too that since increasing pressures produce also the effects of decreasing temperatures, not only the behavior of silica in the cold secondary rocks, but its behavior in primal or magmatic waters must be brought into view. In short, the problem of petrification is one of the broadest and most far-reaching in either geology or geochemistry. It is a problem then which should not be approached in the older or isolated trial manner. Nor need it be, since all the foreground has been cleared, especially so by the results reached in the Geophysical Laboratory of the Carnegie Institution during the past ten years.

As long since urged, the value of the cycadeoids rests on the fact that they prove to be the key, as it were, to a very great group of Mesozoic and earlier times, a greater group of flowering gymnosperms vastly more variant and extended than the conifers. In that flowering group, the greater field of investigation lies. In our more immediate studies of the cycadeoids of heavy-stemmed type, the chief objective is further illustration. There are, to be sure, a few species needing better definition in the specific sense, and there

remain some generic values to consider, as in the case of the free-flowering *Monanthesia* of the San Juan basin, of which there prove to be at least three distinct species. There is also the type from the Trinity beds of Texas which should be called *Williamsonia dyeri* instead of *Cycadeoidea*. But in the main, the family here concerned is made up of types as nearly like each other as species of oaks. It is now one of the best seen families of antiquity, and just because it is such a striking type, its free illustration and yet better coordinated study in the laboratory and field may be defended. While in that sense the projected development of the Fossil Cycad National Monument is being set forward as directly and effectively as circumstances, money and sentiment may permit.

Campbell, Ian,¹ and John H. Maxson, California Institute of Technology, Pasadena, California. *Geological studies of the Archean rocks at Grand Canyon.* (For previous report see Year Book No. 33.)

Due to various circumstances, no field work was prosecuted during the season 1934-35. Considerable time and thought were devoted to the problem of how best to accomplish a thorough study of the Archean section despite the unfavorable terrain. The possibility of a boat expedition down the Colorado River from Lee's Ferry was investigated at length and this now appears to offer the only feasible method. A detailed report on this plan has been submitted. Here it will only be pointed out that: (1) almost all the exposures of Archean rocks, and certainly all the best ones, occur along the Colorado River, close to the water line; (2) in a great many instances it is impossible, and in many others it is extremely hazardous, to attempt to reach many portions of the section on foot or by pack train; (3) the difficulty and slowness of travel on the Tonto platform make the mapping of even a small section of the Archean tedious and costly, since so large a portion of each working day must be spent merely in trying to reach the Archean outcrops; (4) boats offer the only means of reaching many parts of the section, and offer much the easiest means of getting to all parts of the section. Careful inquiry has established the fact that the hazard of this method of transportation, while considerable in the popular mind, is actually very slight provided that well-designed equipment is used and that competent boatmen are in charge of the navigation.

Pending the development of plans, the laboratory investigation of specimens collected on earlier field seasons has continued, and a considerable amount of petrographic data is at hand. Unfortunately the geologic relations of most of the units studied petrographically are uncertain because of the inability thus far to gain access to the critical areas where contacts might be exposed. This feature of the Archean section was emphasized as early as 1915 by Noble² when he pointed out that in almost no case was it possible to determine the relations between any of the major rock types he had delineated, because in each instance the contact occurred at places inaccessible from the Tonto platform. The detailed petrography is reserved there-

¹ Balch graduate school of the geological sciences, California Institute of Technology, Pasadena, California.

² U. S. Geol. Surv. Prof. Paper, 98-I. p. 109, 1915.

fore for a later time when there may be opportunity for presenting along with it the broader geologic and petrogenic relationships which are of fundamental importance in the study.

For the benefit of other students of the Archean, it seems desirable at this time, however, to make available chemical analyses of several of the important rock types now recognized. This is presented in table 1.

No. 22 is the "Garden Creek Granite," a light pink medium coarse-grained granite occurring at the junction of Garden and Pipe Creeks.

No. 40 is a ferruginous quartzite ("iron formation") from Pipe Creek.

No. 211 is the "Phantom Granite" from the type locality on Phantom Creek. This is a light-colored medium- to coarse-grained quartz-monzonite, showing quartz, microcline, oligoclase and biotite in the mode.

No. 270 is a garnet-sillimanite gneiss, containing also quartz, albite and biotite, from the south bank of the Colorado, below Granite rapids.

TABLE 1—Chemical analyses¹ of Archean rocks at Grand Canyon, Arizona

	No. 22	No. 40	No. 211	No. 270	No. 273	No. 315	No. 344	No. 356	No. 363
SiO ₂	72.10	55.30	72.05	61.75	48.20	76.00	59.50	89.80	51.10
Al ₂ O ₃	14.68	Traces	15.30	15.16	14.56	14.20	15.20	4.56	10.20
FeO	.74	38.62	.50	2.34	2.43	1.32	1.50	.83	.12
MgO	.87	1.05	1.48	8.88	13.20	.60	5.46	1.63	2.85
CaO	.39	.75	.52	4.25	5.54	.58	4.96	Traces	.54
Na ₂ O	.80	1.75	2.20	2.00	8.60	.60	5.10	.60	17.92
K ₂ O	3.02	Traces	3.76	.70	2.28	Traces	2.79	.89	.53
H ₂ O +	6.70	Traces	3.68	2.05	.42	2.65	2.81	.64	2.00
H ₂ O -	.45	1.80	.35	.80	1.40	3.30	1.50	.30	1.10
TiO ₂	.10	.10	Nil	.40	.20	.30	.25	.15	.50
P ₂ O ₅	Nil	.20	Traces	1.05	1.55	.40	.55	.55	.38
MnO	Trace	.32	Traces	.15	.12	Traces	.34	Trace	Traces
CO ₂	Nil	Trace	Nil	.32	.26	Nil	.12	Nil	.42
S	Trace	Nil	Nil	Nil	.90	Nil	Nil	Nil	12.20
	Trace	Nil	Traces	.....	.32	Traces	.....	.....	.....
	99.85	99.89	99.84	99.85	99.98	99.95	100.08	99.95	99.86

¹ All the analyses are by W. H. Herdman, Glasgow.

TABLE 2—C. I. P. W. classification of the igneous rocks in table 1

	No. 22	No. 211	No. 273	No. 344
Q.....	27.06	29.52	2.16	11.94
or.....	39.48	21.68	2.22	16.68
ab.....	25.15	31.96	19.39	23.58
an.....	3.89	10.84	28.36	20.57
C.....	1.12	1.12	.....	.....
di.....	.....	.....	7.49	2.26
hy.....	1.16	3.68	29.43	19.36
mt.....	0.93	0.70	3.48	2.09
il.....	.....	.....	3.04	1.06
ap.....	.....	.....	.....	0.67
Classification.....	I. 4.1.3 Liparose	I. 4.2.3 Toscanose	II. 5.4.4 Auvergnose	II. 4.4.4 Bandose

No. 273 is an amphibolite from Boucher Creek. It consists chiefly of bluish-green hornblende, with small amounts of quartz, albite and secondary calcite and pyrite. Its igneous character is obvious from the analysis. It appears to belong to a volcanic series interbedded with the quartz-sericite schists of sedimentary origin in this section and was probably originally a diabase flow.

No. 315 is from a sandstone lenticle in the rather slightly metamorphosed, cross-bedded, quartz-sericite schists of Lone Tree Canyon.

No. 344 is from a massive, moderately coarse-grained granodiorite on the Bass trail.

No. 356 is from a quartzite in the Inner Gorge, west of Monument Creek. It is close to and very similar to the quartzite on which the ripple mark, reported last season, occurs.

No. 363 is from a metamorphosed calcareous concretion occurring in the quartz-sericite schists of Boucher Creek.

One of the interesting studies completed during the year was on this calcareous concretion. The chemical analysis and the petrographic examination have both confirmed the suggestion made in the field, that these curious structures represent metamorphosed calcareous concretions. The country rock is a cross-bedded quartz sericite schist which was originally an argillaceous sandstone. The concretions are roughly ellipsoidal and their major axes, up to three feet in length, are mostly oriented parallel to stratification of the enclosing schists. Because lines of stratification in some instances pass from the schist into the concretions, they are believed to be epigenetic.

The concretions are composed principally of a fine-grained mosaic of calcite and quartz. Occasional porphyroblasts of a green amphibole and of garnet poikiloblastically enclose the groundmass minerals.

Significant as the concretions are in confirming the sedimentary origin of the Vishnu schist, they are more important in indicating the character and intensity of metamorphism. The intimate occurrence of quartz and calcite implies that pressure was high but that only a moderate degree of intensity (in interesting contrast to the high intensity evidenced by the sillimanite gneiss farther east in the section) was here reached. Thus, while the development of biotite and garnet in the concretions indicates that metamorphism has passed the lowest stages, the poikiloblastic character of the garnet and amphibole, together with the occurrence of the latter, rather than pyroxene, indicate that the highest stages of metamorphism were not attained.

A feature, not directly connected with Archean rocks but one which is of some importance in dynamic geology and to which some study was accorded because of its striking development within the Inner Gorge, has been called "stream fluting." In this process swiftly moving sand or silt-laden water currents sometimes abrade grooves, elongate in the direction of flow, in stream boulders and in the bed rock of the stream channel.

While special conditions of current velocity and content of suspended matter are necessary for the development of conspicuous flutes, the process is probably quite generally operative, although the results of its action may be either slight or concealed. The concept introduced by fluting is that turbulent flow is important in stream erosion and that under certain condi-

tions fluting is so effective that boulders may be greatly reduced *in situ* and may, during this reduction, retain their angularity.

During the coming field season, pending negotiations on a boat expedition, it is hoped to extend the Archean section in the two areas where metamorphism has been relatively slight and where, therefore, the possibilities of interpretation are correspondingly greater. The first area is to the west of Boucher Creek; the second in the vicinity of Lone Tree Canyon.

Hinds, Norman E. A., *Researches on Algonkian formations at Grand Canyon National Park.*

Field studies of Beltian formations exposed in the Grand Canyon of the Colorado River were continued during June, July and August 1935. Acting as field assistant was W. H. Swayne, graduate student in geology at the University of California. Mapping of Chuar exposures in the eastern part of the Canyon was completed and a composite section was measured in Nankoweap and Chuar Valleys. Partial sections were measured elsewhere. Additional collections of Chuar sediments were obtained for laboratory study. Unkar exposures along Tapeats Creek and adjacent parts of the Colorado River gorge were mapped where accessible; part of the area along the Colorado River can be reached only by boat. Laboratory studies of Unkar collections and data were carried on at the University of California by C. E. Van Gundy, who is making a special study of that group.

CHUAR GROUP

Detailed examination of Chuar strata shows that, while no break in sedimentation is present, the group can be divided into eight units satisfactory for mapping purposes and possessed of moderately distinct lithologic characters. Thus the complete stratigraphic column of Beltian rocks at the Grand Canyon is—

Cambrian (Middle)

Tapeats sandstone

Unconformity—Grand Canyon orogeny and Ep-Algonkian peneplanation.

Algonkian (Beltian)

Chuar group	8. Red sandstone.....	50 feet
	7. Red, green, gray, and black shale; oolitic and algal limestone; sandstone	1467
	6. Red sandstone with thin beds of red shale. Oolitic hematite in places....	50-140
	5. Red, green and gray shale; thin beds of sandstone and limestone.....	262
	4. Alternating beds of limestone, red, green, gray and black shale, and occasional sandstone. Most of the limestones show algal structures....	1152
	3. Red, green and gray shales alternating with thin beds of sandstone. A few thin beds of limestone.....	1524

2. Red, green, gray and black shale with frequent thin beds of sandstone and a few of limestone. At the top is a bed of calcareous tufa underlain by a thick algal limestone.....	578
1. Brown, magnesian limestone.....	50-150
	<hr/> 5133-5323
Disconformity	
Nankoweap group.....	400
Disconformity	
Unkar group 4. Dox sandstone and lavas.....	2297
3. Shinumo quartzite	1564
2. Hakatai shale.....	580
1. Bass limestone.....	341
Profound unconformity-Arizonan revolution ¹ and Ep-Archean peneplanation.	
Archean	
Vishnu schists and intrusive granitoid rocks	

The total thickness of the Chuar division corresponds very closely with that of 5120 feet determined by Walcott² in 1883. Walcott considered the magnesian limestone the top of the Unkar and separated from the Chuar by a slight erosional break, but our field study shows conclusively that an erosional unconformity exists at the base of the limestone and not at its top, hence this unit forms the base of the Chuar. Thin lenses of basal conglomerate derived from rocks of the underlying Nankoweap group are locally present. Sedimentation was continuous till the close of Chuar time and was not interrupted by the emission of any volcanics. Deposition appears to have occurred under quiet but shallow marine waters. The sediments are fine-textured throughout and probably were derived from low-lying lands. The entire sequence is characterized by frequent alternations of the various lithologic types. Limestone is abundant, but occurs only in thin beds, many of which show structures commonly interpreted as algal. Details and generalizations regarding the sedimentation must await completion of laboratory studies now in progress.

Except for the algal structures, no fossils were found at any horizon in the Grand Canyon Algonkian. Markings which possibly may be burrows or trails are not uncommon. Indirect evidences of life are the abundant carbonaceous shales and occasional carbonaceous limestones. A number of limestones give off strongly fetid odors when broken.

Chuar deposition was close by the building of the Grand Canyon Mountains which were almost completely destroyed by Middle Cambrian time and the Ep-Algonkian peneplain was evolved. All known residuals rising above the general level of this plain were buried during the Bright Angel epoch, second division of Cambrian time in this region.

¹I propose the term *Arizonan* for the great Archean deformation, metamorphism and granite invasion immediately antedating the erosion of the principal pre-Cambrian peneplain in western North America since all of these features are so magnificently exposed over wide areas in the state of that name.

²C. D. Walcott, *Pre-Cambrian Igneous Rocks of the Unkar Terrane, Grand Canyon, Arizona*, U. S. Geol. Surv., 14th Ann. Rept., Pt. II, 510, 1894.

BELTIAN AND UNCOMPAGHAN

So-called Algonkian rocks in central and southern Arizona, in the San Juan Mountains of Colorado, and in the Wasatch Mountains of Utah were examined during the 1935 season. These studies, continued from 1933 and 1934, show that two groups of strata separated from each other by a notable hiatus exist. The earlier group, lying with profound unconformity upon highly deformed and metamorphosed Archean rocks, include quartzites, conglomerates, slates and tillite of the Wasatch, Uinta, Oquirrh and other ranges of northern Utah; the Needle Mountains group of quartzite, conglomerate and slate of the San Juan Mountains, Colorado; and the Mazatzal quartzite conglomerate, slate, and rhyolite of central and northeastern Arizona. Following deposition of these sediments, which are dominantly arenaceous, there occurred through southwestern Colorado and Arizona at least an epoch of intense folding and faulting accompanied by intrusion of granite which resulted in the elevation of mountains of considerable magnitude. For this orogeny and for the granite associated with it, I propose the term Mazatzal from a range in central Arizona where features of the disturbance are splendidly exposed. In northern Utah some deformation occurred but its magnitude has yet to be ascertained; so far as is known no granite intrusion accompanied the folding in this section. In most places the unconformity between the Utah quartzite series and the overlying Cambrian is moderate.

Later came deposition in local basins of pre-Cambrian strata which include the Grand Canyon series, the Apache group of south central Arizona, an extensive sequence in southeastern California which may have been continuous with that at the Grand Canyon, and the Belt series of northern United States and southern Canada. Possibly also the Algonkian of the Texas Llano should be included. For these deposits I have proposed the term Beltian.¹ The Unkar division of the Grand Canyon series and the lower part of the Apache group in south central Arizona contain considerable quantities of quartzite derived from the older series which apparently had undergone material erosion before Beltian deposition began.

Beltian deposition was closed in the Grand Canyon area by the Grand Canyon orogeny which appears to have affected only a small area. Elsewhere deformation was epeirogenic, though local slight and occasional sharp flexuring accompanied it.

During time of deposition of the earlier quartzites, some rhyolitic lavas were erupted in central Arizona. The granite which invaded these strata during the Mazatzal revolution very evidently considerably antedates the Beltian rocks. While the latter were being laid down, diabase sills and dikes were emplaced within them and basalt flows were erupted in all of the basins of deposition. In no area which I have examined does pre-Cambrian granite intrude Beltian strata.

Because of the existence of two widely separated series of strata which have been called Algonkian, important problems of classification and nomenclature arise. The older series lies with profound unconformity upon a very

¹ N. E. A. Hinds, *Ep-Archean and Ep-Algonkian Intervals in Western North America*, Carnegie Inst. Wash. Pub. No. 463, 6-7, 1935.

even, peneplained surface eroded in highly deformed and metamorphosed rocks; this surface I have considered to be the Ep-Archean peneplain. However, the older series may be a younger Archean group roughly equivalent to the Huronian of the Lake Superior region, and the peneplain below the approximate equivalent of the Epi-Laurentian peneplain. On the other hand, because of the notable difference in degree of deformation and metamorphism, it may be more satisfactory to consider the various quartzite series post-Archean. Certainly the erosion surface below these rocks is a much more perfect peneplain than that above. The greatest deformation, the most intense and universal metamorphism, the principal intrusion of granite, the longest erosion interval and the most perfect peneplanation antedate the quartzites. Much additional field study will be needed to yield light on this problem.

The later pre-Cambrian rocks in central Arizona lie unconformably on the older quartzites; elsewhere they are not in contact, but, as noted above, quartzite débris is present in the Beltian of the Grand Canyon and south central Arizona. Also the second series, where not affected by much later granites, shows no or moderate metamorphism, while the quartzites exhibit a more advanced stage. That a notable break exists between the two is nowhere open to doubt.

It is evident that both the older quartzites and the Beltian strata can not be regarded as Algonkian and that correlations previously suggested between the two can not be supported by field evidence. For the present I prefer to call the Beltian rocks Algonkian. Until the older quartzites are further studied and other areas of pre-Cambrian rocks in western North America are examined, it will not be possible to assign them to a definite place in the time scale, though now I am inclined to think it better to reserve the term Archean for the highly deformed and metamorphosed basement upon which the later rocks rest and to establish a new periodic division for the quartzites and equivalent rocks. If such a period be established, it should be considered the first of the Paleozoic. The need for a pre-Cambrian era later than the Archean becomes less evident as further study is carried on.

For all of the earlier quartzite groups and their equivalents in western North America I propose the general term Uncompahgran from the group name of that series described by Cross and others in their study of the magnificent exposures in the San Juan Mountains, Colorado.

While mapping the Algonkian formations at the Grand Canyon, it was found possible to complete a geological map of the Vishnu and Bright Angel quadrangles composing the eastern part of the National Park.

PHYSICS

Committee on Coordination of Cosmic-Ray Investigations. *Progress report for the period July 1934 to June 1935.* (For previous reports see Year Books Nos. 32 and 33.)

The special Committee on Coordination of Cosmic-Ray Investigations held a meeting in December 1934. Its several members conferred at different times with Doctors A. H. Compton, T. H. Johnson, and R. A. Millikan, research associates of the Institution, as well as others interested in the cosmic-ray field. Professor H. A. Bethe, following the Conference on Theoretical Physics held in Washington April 19-21, 1935, prepared a memorandum on cosmic rays of which a copy is attached.

The last of the seven precision cosmic-ray meters, after the design of Doctors A. H. Compton and R. D. Bennett and constructed in the instrument-shop of the University of Chicago, were completed and tests at Chicago were made late in June 1935. Meter No. C-1,¹ after being exhibited at the Pittsburgh meeting of the American Association for the Advancement of Science in December 1934, was shipped to the Cheltenham Magnetic Observatory for installation there following arrangements made for the Committee by the Department of Terrestrial Magnetism. Permission to place the meter at Cheltenham was given by the Director of the United States Coast and Geodetic Survey "in view of the undoubtedly close relations existing between phenomena at present observed at the Cheltenham Magnetic Observatory and cosmic radiation." A small existing frame building at the Observatory was made available and was appropriately insulated against rapid changes in temperature. Dr. R. L. Doan, of Dr. Compton's staff, and Mr. S. E. Forbush of the Department of Terrestrial Magnetism, with the assistance of the staff at the Observatory, installed the meter. Recording began early in January 1935. As was to be expected in the development of a precise recording-instrument of this type, some difficulties were encountered in continuous operation. The most serious of these arose from some particles of dust and lint, which had not been removed completely before assembly, in the argon bomb. The high electric field oriented these until they bridged the air-gap in the neck of the bomb. After replacing the bomb of meter C-1 with that of meter C-3, March 18, 1935, despite several minor interruptions, practically continuous photographic records have been obtained. Improvements to eliminate these defects in all the meters were made by slightly enlarging the air-gaps in the bombs, by greater precautions in removing all dust and lint before sealing with carefully filtered ceresin wax, and by minor changes in the electrical circuits.

¹For purposes of record the survey type of meter originally used by Dr. Compton and his associates in the world-survey is designated type A; the type-A meter adapted for stratosphere flights is designated type B; and the precision cosmic-ray meter intended for continued operation at fixed stations is designated type C. The respective instruments of each type are numbered 1, 2, 3, etc., thus A-1, A-2, A-3, etc.

The operation of the meter at Cheltenham under the joint supervision of the Department of Terrestrial Magnetism and of the United States Coast and Geodetic Survey has furnished information as to the difficulties which may be expected in an apparatus of the kind to be kept recording continuously for several years under conditions prevailing at outlying stations. On the basis of this experience, Mr. Forbush has amplified the instructions for installation and operation of the meters as originally prepared by Dr. Doan and himself. These are now being prepared finally as a manual with circuit-diagrams and illustrations for use at the stations.

[Meter No. C-2 was received at the Huancayo Magnetic Observatory (11,000 feet above sea-level), September 17, 1935. This meter is to be mounted in a thermally insulated room in the anemograph and laboratory building at the Observatory.]

Following the policy of the Committee, meter No. C-1 was compared, before being sent to Cheltenham, with meter No. C-0, which is kept as the standard instrument at the University of Chicago. During the spring of 1935 the other six meters were operated simultaneously in parallel at the University of Chicago for some six weeks. From the records so obtained, information as to relative performance and statistical aspects has been computed.

Information regarding the probable extreme ranges of air-temperature and of barometric pressure likely to be encountered at each station in the proposed network was obtained so that individual instruments might have appropriate ranges of record for temperature and pressure; in this the United States Weather Bureau gave advice. The Committee now has under way, through the Department of Terrestrial Magnetism and Dr. Compton, final inquiries and arrangements for the installation of meters as originally planned at three other stations in Greenland, Mexico and New Zealand. It is hoped a fourth may be located eventually on Pike's Peak or on Mount Evans, both some 14,000 feet above sea-level. If so, there will be six stations in the net with a standard at Chicago.

The Committee hopes with the cooperation of Dr. B. F. J. Schonland, who has supervision of the cosmic-ray recording being done with Dr. Steinke's instrument at Cape Town, that it may be possible to continue recording at that station during 1935 and at least 1936. This should not only give useful data extending the geographic limits of the world-net of stations proposed, but also coordinate the data from the Steinke network of stations with that of the Institution.

Dr. J. Agostinho, Director of the Meteorological Service of the Azores, kindly suggested to the Committee the feasibility and possible desirability of installing one of the meters on Pico Island; a site at 2343 meters above sea-level, comparatively easy of access for care and attendance and with small fixed expense would be available there. For the present the Committee feels that consideration of this location should be deferred pending development of its original plans (see reports in Year Books Nos. 32 and 33).

The meter of the type A, previously used by Dr. Benade in the field and later by Professor Blackett in special work at London, was loaned to Dr. Alda Sibley, American Rhodes Scholar, who planned to use it on board

steamer during a world-cruise sailing early in July 1935 and touching at Ceylon, Singapore, Philippine Islands, Hawaii and California.

With the return of the Second Byrd Antarctic Expedition, Dr. T. C. Poulter, in charge of the scientific work, submitted a preliminary report showing the results of cosmic-ray observations made with the type-A meter used during the Expedition. Because of a leak developed after arrival at the base-station, it was necessary to refill the bomb with carbon-dioxide gas (a supply of argon for renewal was not available). Pending the recalibration of the bomb, to be made at the University of Chicago by Dr. Compton and his associates, and the preparation of the paper on the results as planned by Doctors Compton and Bramhall, detailed account of this work is deferred until a later report. It may be noted, however, that a series of cosmic-ray observations was obtained on the *Jacob Ruppert* en route from Panama to New Zealand and thence to the Barrier by Dr. E. H. Bramhall and Mr. A. A. Zuhn; between April 1934 and February 1935, visual observations at fortnightly intervals were made at the base-station Little America for a total of 800 hours. Other data were obtained on a flight of several hours' duration above the camp at an altitude of 11,000 feet. Upon the return of the Expedition to New Zealand, 37 hours of measurements were made at the Otago University, Dunedin, March 3 to 6, 1935, at the station occupied by Dr. Compton in 1932. Comparison with the latter's results will afford a basis for recalibration of the instrument, although not so satisfactory a one as that to be made at Chicago.

Excellent progress during the year was made by Doctors Compton, Johnson and Millikan and their associates as indicated in the three attached reports. Suggestions for continued cosmic-ray research submitted individually by them for the calendar year 1935 were all highly regarded by the Committee. However, because of the limited funds available to the Institution from the Carnegie Corporation for cosmic-ray research and following its adopted policy to eliminate duplication of items, the Committee recommended consideration of a limited number only of the suggestions. President Merriam approved the recommendations made for apportionment of funds in 1935 for items as follows: (1) Continuance of program for precision cosmic-ray meter installations; (2) mountain observations in connection with a program of high-altitude research; (3) temporary services of computer to compile asymmetry measurements already obtained and for field-expenses of additional measurements of this kind; (4) apparatus and expenses for absorption-measurements; and (5) compensation for full- and part-time services of assistants for work being done by Dr. Millikan. The unexpended balances from allotments made for items indicated in previous reports have been continued available for the purposes originally named.

The three cosmic-ray electroscope-recorders of the Millikan-Neher type ordered by the Committee from the California Institute of Technology were nearing completion at the end of the year.

That the cosmic-ray researches supported have netted continued valuable returns is evidenced by perusal of the attached reports. The installation of precision cosmic-ray meters at the remainder of the world-wide net of stations will be realized, it is expected, during 1936. The work at these stations

must be maintained for a number of years so that the data accumulated will meet the statistical requirements for adequate analysis.

W. S. ADAMS.
JNO. A. FLEMING,
FRED E. WRIGHT.

MEMORANDUM ON COSMIC RAYS, SUBMITTED BY H. A. BETHE, CORNELL UNIVERSITY, ITHACA, NEW YORK.

INFORMATION OBTAINED FROM MAGNETIC LATITUDE-EFFECTS

(a) Probably all the primary cosmic particles are charged (or at least, practically all of them). Proof: Latitude-effect at high altitude. Clay¹ finds at 15-km. altitude (= 10-cm. mercury = 1.3-meter water-equivalent) and 18° south geomagnetic latitude a cosmic-ray intensity of 12 ions/cc./sec./atmosphere, that is, about five per cent of that at 50° geomagnetic latitude and the same altitude.²

(b) The majority of the particles (95 per cent) has energies below about 18 billion volts. Proof: Same experiments of Clay. According to the theory of the influence of the earth's magnetic field (Fermi and Rossi, Lemaitre and Vallarta, etc.³), 18-billion-volt particles are half as numerous at the magnetic equator as at the poles.

(c) The "showers" are not produced by all cosmic rays, but only by part of the radiation. Proof: The latitude-effect is different for showers than for the total radiation. For example, at sea-level, the full intensity of the showers is reached at geomagnetic latitude 29° (Johnson), while the total radiation reaches full intensity only at latitude 50°.

(d) The primary shower-producing radiation loses energy at a faster rate than the total radiation. Proof: Smaller latitude-effect for showers [compare (c)]. For reaching the earth at latitude 29°, a particle has to have at least about 8-billion-volt energy outside the atmosphere;⁴ for reaching it at latitude 50°, only about 2 billion volts. Thus the experiments show that the primary shower-producing radiation loses 8 billion volts of energy when traversing the atmosphere, while there are non-shower-producing cosmic particles which lose only 2 billion volts.

EAST-WEST EFFECT

(a) The shower-producing cosmic rays consist of an approximately equal number of positive and negative particles, with a slight preponderance of positives. Proof: Absence of east-west effect on showers, in spite of presence of latitude-effect, especially at higher altitudes (4300 meters, see Johnson⁴).

(b) The non-shower-producing rays are all, or practically all, positive. Proof: Strong east-west effect of total cosmic radiation, many more particles from west than from east.⁵

ABSORPTION-MEASUREMENTS

In the primary cosmic rays there are at least three different groups of particles:

(a) When the data on cosmic-ray intensity at high altitude are analyzed for the distribution of the particles in range (Compton⁶), a group of particles with ranges less than 3.5 meters of water-equivalent is found (group A) and one group with ranges greater than 3.5 meters (B), separated by a pronounced minimum in the intensity-range curve at 3.5 meters.

(b) The cosmic rays at lower altitudes (air pressure greater than 3.5 meters of water) still consist of two components, one shower-producing (B), the other not (C). The shower-producing component B is more readily absorbed than C. Proof: Showers increase more rapidly with increasing altitude than does the total radiation^{4, 7} and decrease more rapidly in water.⁸

(c) The primary shower-producing radiation B loses energy at the rate of about 800 million volts per meter of water (or water-equivalent). This figure follows (1) from the minimum range of B-particles, namely, 3.5 meters at 50° latitude in conjunction with the minimum energy required for electrons in order to reach the earth at latitude 50°, namely, 2.6 billion volts, (2) from the latitude-effect of showers at sea-level [compare 1(d)] which shows that about 8 billion volts are necessary to traverse 10 meters of water-equipment, (3) a slightly smaller value follows from the latitude-effect of showers at 4300-meter altitude (Johnson⁴). At this altitude, the full shower-intensity is reached at about latitude 50°, which shows that 2.6 billion volts are necessary to traverse the corresponding air-layer (5.5 meters water-equivalent).

(d) The particles of component C lose energy at the rate of 200 million volts per meter of water. Proof: Two billion volts are required to reach the earth's surface [1(d)]. (This figure is based on the assumption of protons for component C [compare 5(d)].)

(e) The maximum energy of component C is at least 100 billion volts, since cosmic rays are found at 500-meter depth in the Red Sea (Clay¹). The number of particles decreases rapidly with increasing energy (absorption-curve).

SHOWERS

(a) Showers consist of pairs of positive and negative electrons. Occasional single positive or negative electrons can be accounted for by absorption of the other partner.

(b) The pairs originate from various points lying close to each other. It is definitely established that they do not all come from one point. It can not be said whether more than one pair may come from one center or not. Reason: Pairs coming from two different points lying in the direction of motion of the electrons appear as if coming all from the same point.

(c) The agency directly responsible for the showers is a non-ionizing radiation. Proof: Pairs are produced in lead plates interposed in cloud-chamber, without any track being detectable above plate.

(d) The directly shower-producing radiation is probably a gamma-radiation. Reasons: (1) Prolific production of electron-pairs to be expected for high-energy gamma-rays; (2) non-ionizing nature of radiation; (3) radiation has to have small rest-mass—otherwise shower-electrons would go in all directions rather than forward (momentum-considerations), also secondary protons and other heavy particles would be emitted rather than electrons,

which excludes neutrons as shower-producing radiation; and (4) absorption of shower-producing radiation in various materials proportional to Z^2 , as expected for high-energy gamma-rays.⁷

(e) The directly shower-producing radiation can not be primary. Proof: The number of triple counter-coincidences below lead, which indicates the number of showers, increases first with increasing thickness of the lead, then decreases very rapidly, then reaches a constant value equal to about half the maximum. Interpretation: Increase due to electron-pairs, produced in the lead by the directly shower-producing radiation coming from the air; decrease = absorption of shower-producing rays from air; this decrease should continue unless new "directly shower-producing radiation" is produced in the lead; hence shower-producing gamma-rays of secondary nature.

(f) The primary shower-producing radiation is charged. Proof: Latitude-effect.⁴

NATURE OF THE COSMIC RAYS

(a) Most probably the primary shower-producing radiation consists of electrons, positive and negative. Electrons, in distinction to protons, are expected to emit gamma rays with very high probability. Only a gamma ray is emitted; it produces very easily an electron-pair. Each of the pair of electrons emits gamma radiation, etc. This rapid multiplication may account for the shower-production.

(b) The most probable energy of shower-electrons is about 13 million volts (Anderson⁹). This is in accord with the multiplication-theory, since the multiplication obviously comes to an end when the electrons are so slow that they lose energy more rapidly by producing ions than by emission of radiation which is the case below 10 million volts (for lead).

(c) The production of showers accounts for the large energy-loss of the shower-producing cosmic rays as compared with the non-shower-producing component *C* [compare 3(c), 3(d)]. The energy-loss of cosmic-ray electrons by production of showers (emission of gamma rays) is, however, about ten times smaller than expected theoretically, thus showing the failure of the theory for very high-energy electrons in quantitative respects.

(d) The penetrating component *C* (non-shower-producing) may be interpreted as protons. The energy-loss agrees with theoretical expectation, assuming that protons lose energy only through ionization.

(e) Component *A* may be attributed to alpha particles. It shows latitude-effect¹ and its range agrees well with expectations for alpha particles. The minimum energy of alpha particles required for reaching the earth at latitude 50° is 2.5 billion volts, the corresponding range about 1.5 meters of water.

REFERENCES

- ¹ Clay, *Physica*, vol. 1, 363 (fig. 9).
- ² Bowen, Millikan, and Neher, Report to London Conference on Nuclear Physics (fig. 6).
- ³ Lemaitre, Vallarta, and Bouckaert, *Phys. Rev.*, vol. 47, 434, where older references are given; for numerical values, see Lemaitre and Vallarta, *Phys. Rev.*, vol. 43, 87.
- ⁴ Johnson, *Phys. Rev.*, vol. 47, 643.
- ⁵ E. G. Auger, Report to London Conference on Nuclear Physics.
- ⁶ Compton and Stephenson, *Phys. Rev.*, vol. 45, 441.
- ⁷ Rossi, Report to London Conference on Nuclear Physics.
- ⁸ Pickering, *Phys. Rev.*, vol. 47, 423.
- ⁹ Anderson and Neddermeyer, Report to London Conference on Nuclear Physics.

Compton, A. H., University of Chicago, Chicago, Illinois. *Studies of cosmic rays*. (For previous reports, see Year Books Nos. 31-33.)

Our cosmic-ray studies during the past year have been concerned chiefly with three problems: (1) The geographic distribution of cosmic rays, completing a program that has been under way since 1931; (2) analysis of the composition of cosmic rays using data on the intensity of the rays at various altitudes; (3) the factors which cause variations in the observed intensity of cosmic rays.

COSMIC-RAY SURVEY

In our earlier reports we have described our measurements of cosmic-ray intensity made at many different stations widely distributed over the earth. During the past year data have been reported from our meters used by Professor Rossi in Eritrea, by Doctors Poulter and Bramhall in Antarctica and the South Pacific, and by Mr. Sibley in the Indian Ocean and the Philippines. Our survey and those by independent observers have now covered as much of the earth as we consider profitable to investigate by the method of short-time observations such as we have been using. The occurrence of occasional variations of several per cent in the cosmic-ray intensity at fixed locations, renders of little value further measurements of short duration even though of higher precision. Accordingly we do not plan to carry this survey further, though we are proceeding with a long-time study of the intensity at a few fixed stations located at widely different latitudes, as described below.

We are now compiling the results of these studies and those of other observers in the form of a world map which will show graphically the distribution of the cosmic rays. A significant finding from this compilation is that the curves of equal cosmic-ray intensity follow within experimental error the curves of equal frequency of auroral displays, indicating that both phenomena are affected by the earth's magnetic field in the same manner. Both the magnetic latitude- and longitude-effects show themselves clearly.

The point of chief interest that has come from this survey is that the cosmic rays are affected by the earth's magnetic field. Some evidence that cosmic rays do not have the same intensity in all parts of the earth had been found by Professor Clay of Amsterdam before this survey was begun. Our studies first showed the correlation of these variations with the earth's magnetic field, and the rapid increase in the magnitude of the variations at higher altitudes. From these results it follows that an important part of the cosmic rays consists of electrified particles. The general acceptance of this conclusion has come largely as a result of our study.

ANALYSIS OF THE COMPOSITION OF COSMIC RAYS

In considering the cosmic-ray observations taken on our Century of Progress balloon flight, it became evident that such data should afford a means of analyzing the various electrical components of the cosmic rays. The earth serves, in fact, as a huge magnetic mass-spectrograph, similar in principle to that used for measuring the atomic weight of positive rays. Because of the action of the earth's magnetic field on the incoming rays, the latitude at which they appear gives one measure of their energy. The depth through

the atmosphere to which they penetrate affords another measure. By comparing these two values it should be possible to calculate both the energy of the particle and its ratio of charge to mass, which latter would identify its nature. Our studies during the past year have shown us the type of data which must be obtained to make such an analysis complete and definite. Using the information now at hand from our own and other experiments, we are thus led to the following tentative analysis:

The most prominent part of the primary cosmic rays whose effect is observed above sea-level consists of nearly equal parts of positive and negative electrons. Below sea-level is a very penetrating component for which the identification as protons seems to be required, though certain difficulties remain with this assumption. At very high altitudes there is some evidence for the existence of a relatively absorbable component which may consist of alpha particles. We have been unable to find any evidence of electrically neutral rays as a component of the cosmic rays that strike the earth's atmosphere. In fact, a comparison of the stratosphere balloon data taken on our Century of Progress balloon in northern United States with those obtained by Clay using instrument-carrying balloons in Java seems to show that at least 98 per cent of the cosmic rays striking the earth are affected by the earth's magnetic field and are hence electrical.

In order to make this analysis of cosmic rays more complete, we are proceeding with further high-altitude studies of cosmic-ray intensity and with more refined measurements of the latitude-effect, and are trying to get additional data on the penetrating power of rays of measurable high energies. If these experiments can be performed with sufficient precision, our method of cosmic-ray analysis should supply a definite answer to the nature and the amount of each of the components of the cosmic rays.

VARIATIONS IN THE INTENSITY OF THE COSMIC RAYS

Since the early observations by Hess, it has been known that the ionization produced by cosmic rays is nearly independent of the time of day, and our geographic studies have shown likewise that, except for the effect of the earth's magnetic field, this ionization is nearly independent of the location on the earth. Such major observations indicate that in space the rays are nearly isotropic. From this fact the inference has been drawn that the cosmic rays come from very remote space, a conclusion which has obvious significance regarding their method of production.

More refined measurements by many observers, including especially Hess, have established the existence, however, of minor variations in the ionization produced by cosmic rays. The most prominent of these is that due to changes in the barometric pressure, which correspond to changes in the thickness of the absorbing layer of air through which the rays must pass. Other systematic changes with solar time and sidereal time have been suspected. In addition to these there are found to be occasional fluctuations in ionization which follow no regular rule and whose origin is unknown. If the cosmic rays originate in very remote space, it is not permissible to ascribe such fluctuations to changes in the intensity of the primary cosmic rays themselves. We should rather look for variations in the local conditions which would account for the changes in the observed ionization. It

thus becomes important to inquire whether it is possible to account for the variations to which cosmic-ray ionization is subject in terms of changes in the local conditions, or whether such changes imply corresponding changes in the strength of the rays as they come from space.

In order to obtain the data from which such a study can be made, we have completed the construction of seven recording cosmic-ray meters, built as described in our last year's report. One of these has been in operation for almost a year at Cheltenham. A second is being installed at the Carnegie Institution's Magnetic Observatory at Huancayo, Peru. Plans for similar installations in New Zealand, Mexico, Greenland, and on Mount Evans, Colorado, are under way. It is the hope of the Carnegie Institution's Cosmic-Ray Committee that records may be accumulated by these instruments over a long enough period of years to find whether seasonal variations and others of like type occur.

Already our use of these meters has brought to light several significant phenomena. Running six of the meters side by side, Dr. Doan has found, over a period of ten days when barometric changes were almost negligible, a definite diurnal variation of amplitude about 0.2 per cent following a sine curve. This variation is similar in type to that observed by Hess and others, though perhaps more decisive in its experimental aspects. Whether such diurnal variation follows solar or sidereal time can not be determined from such short period records.

Auxiliary tests show that large changes in temperature cause no detectable variation in the reading of our meters.

Operating the meters without a lead shield it was found that a large increase in ionization occurred associated with every thunder-storm. Using lead shields of different thickness on different meters, this extra ionization was found to be absorbed at the rate characteristic of the hard gamma-rays from radium. It was at once obvious that the temporary increase in ionization associated with these thunder-storms was due to active deposit of radium carried down by the rain and left on the roof of the building which shielded the meter. The presence of such active deposit in rain-water was observed long ago by C. T. R. Wilson. There can be no doubt that this accounts for a considerable portion of the fluctuations observed by investigators who have used the ionization-chamber with its lead shield open toward the top. The magnitude of the effect is so great that a shield of several centimeters of lead is necessary to make negligible the ionization from active deposit.

A prominent phenomenon with these new meters is that of cosmic-ray bursts. These show themselves by sudden, large deflections of the electrometer. Professor R. D. Bennett, of the Massachusetts Institute of Technology, has carried through a detailed study of the frequency and size of these bursts, using one of our meters at various altitudes from 185 meters to 4300 meters. It was found that the number of the bursts increased with altitude even more rapidly than does the total ionization due to cosmic rays. There is likewise an apparent increase in the average size of the bursts at high altitudes. Simultaneous, independent measurements of a similar type leading to much the same results have been performed by C. G. Montgomery and D. D. Montgomery.

Dr. Doan's tests show further that the bursts are most frequent when the meter is shielded with several centimeters of lead. With no lead shield or with 12 cm. of lead their frequency is less than with 3 or 4 cm. This supports the view now held by many workers in the field that such cosmic-ray bursts are due directly to a readily absorbable radiation, perhaps of the photon-type, which originates above the meter but spends its energy in ejecting ionizing particles from the lead shield.

A further finding with these meters is a confirmation of the observation made by several other investigators that occasionally large fluctuations occur in the cosmic rays which are independent of the barometer and do not follow any regular type of time-cycle. Variations of this type, of the order of 2 per cent, observed in each of six meters placed side by side, have been observed. The origin of such fluctuations is unknown, but may be associated with some such atmospheric phenomenon as changes in the atmospheric-electric gradient.

APPARENT EFFECT DUE TO GALACTIC ROTATION

Astronomical studies by J. H. Oort and others have shown a rotation of the galaxy which carries the earth with a speed of roughly a thousandth that of light toward about declination 47° north and right-ascension $20^{\text{h}} 40^{\text{m}}$. This rapid motion should cause a greater intensity of the cosmic rays on the front side of the earth than on the back. Calculation indicates that this should cause fluctuation with sidereal time of amplitude about 0.05 per cent, when due account is taken of the effect of the earth's magnetic field. We have found that recent data accumulated by Hess and Steinmaurer show a variation with sidereal time having just the predicted amplitude and phase. While this agreement gives a strong presumption that we have here a real effect due to the earth's motion through space, the experimental data may be accounted for also by alternative assumptions.

If this effect due to the rotation of the galaxy is real, there should be a similar variation with sidereal time, with the same phase, in the Southern Hemisphere. Moreover, the intensity of the rays should be slightly greater in the Northern than in the Southern Hemisphere. These two predictions differ from those that would come from other interpretations of the apparent effect. We are accordingly planning measurements with our new recording meters in both the Southern and Northern Hemispheres under conditions as nearly identical as possible, in the effort to find any sidereal effect that is present and also to observe more precisely the relative strength of the rays in the two hemispheres.

It is clear that if the existence of this effect is confirmed, the origin of the cosmic rays must be beyond the galaxy itself. We shall in fact have in such studies a new method of observing the important astronomical phenomenon of galactic rotation. Incidentally, from the magnitude of the observed effect, we should obtain valuable additional evidence regarding the composition of the cosmic rays.

PERSONNEL

During the period from July 1, 1934, to June 30, 1935, the following persons have been employed to assist me in the cosmic-ray researches supported

by the Carnegie Institution: Dr. E. O. Wollan, July 1 to August 31; Dr. R. L. Doan, July 1 to June 30.

During the same period, funds from the Carnegie Institution or instruments owned by the Institution have been supplied through me to aid cosmic-ray research by the following men, whose work has been mentioned in the above report: Professor R. D. Bennett, Massachusetts Institute of Technology; Professor J. C. Stearns, University of Denver; Professor P. M. S. Blackett, Birkbeck College, University of London; Mr. Alden K. Sibley, Oxford University.

My associates and I have published several papers, during the current year, reporting work supported wholly or in part by the Carnegie Institution of Washington. These are listed in the bibliography of this Year Book.

Johnson, Thomas H., Bartol Research Foundation, Swarthmore, Pennsylvania. *Studies of cosmic rays.* (For previous report see Year Book Nos. 32 and 33.)

The survey, undertaken in 1933 for the study of directional distributions of the cosmic radiation, resulted in reasonably accurate values of the east-west asymmetry at two high elevations in Peru, at sea-level in Panama and at sea-level in Pennsylvania, but the measurements made in Mexico had been of an exploratory character and the accuracy was not as great as desired. Because of the importance of the asymmetry measurements for the analysis of the primary radiation, further studies were made with the support of the Carnegie Institution during the summer and fall of 1934 which have improved the accuracy and extended the range of elevations for the east-west asymmetry measurements in and between the latitudes 29° and 50° where most of the change of intensity takes place. Although measurements of the asymmetry and of the latitude intensity variations are sufficient, according to the simple theory, to determine both the relative intensities of positives and negatives in the primary radiation and their distribution with respect to the magnetic rigidity ($Hq = mv/e$), it is necessary to rely upon absorption data for the final identification of the rays, and for this reason as high an accuracy as possible was desired in regard to the dependence of the asymmetry upon the path-length of the rays through the atmosphere, that is, variations of the asymmetric component with respect to zenith-angle and elevation.

For the purpose of the more intensive survey an automatic, multi-directional, cosmic-ray intensity comparator was developed and with it extensive measurements were realized at the following stations, strategically located as regards elevation and latitude: Echo Lake, Colorado; Mount Evans, Colorado; Copilco, Villa Obregon, Mexico; El Pico Nevado de Toluca, Mexico; Vera Cruz, Mexico; Parral, Chihuahua, Mexico; and Swarthmore, Pennsylvania. The measurements at these stations added to those of the 1933 survey in Peru and Panama seem to be sufficient for a reasonably accurate analysis of the primarily cosmic radiation in the range of energies participating in the asymmetry- and latitude-effects in this range of latitudes and in this longitude. The results have been published in the Physical Review.

In applying the results to an analysis of the constitution of the primary radiation, it is necessary to make use of the variations of the intensity with

latitude, but since these differ with longitude, according to the results of Clay, and Millikan and Neher, the analysis meets with an apparent ambiguity. Thus using the latitude-effect for the 75° west meridian the primary rays would seem to be entirely positive. In fact the intensity of the positives as evidenced by the asymmetry is more than enough to account for the observed latitude-effect. On the other hand the larger latitude effect found at the 160° west meridian requires a greater corpuscular intensity than is revealed by the asymmetry, possibly indicating the existence of an additional mixed component of positives and negatives. Furthermore, the longitude-effect, considered as a result of the displacement of the magnetic center with respect to the geometric center of the earth, is not fully accounted for by the positive intensity found from the asymmetry. The discrepancy seems to be greater than can be accounted for by experimental errors and suggests the existence of additional factors in the situation not included in the simple theory which regards the magnetic field of the earth as that of a simple dipole. In fact it seems probable that further study of these discrepancies may constitute a means of studying the earth's magnetic field at great distances from the earth's surface.

Besides the east-west asymmetry studies, the 1934 program of field work included investigations of the north-south asymmetry; the dependence of cosmic-ray showers upon latitude and elevation; the asymmetry of cosmic-ray showers; and the asymmetry of cosmic rays filtered by lead absorbing-screens.

The southern intensity in Mexico (Northern Hemisphere) was found to be greater than the northern intensity at corresponding zenith-angles in accord with the predicted effect of periodic orbits analyzed by Lemaitre and Valarta. The observations could also be explained as a shadow-effect due to the cutting off of some of the curved orbits from the northern directions by the surface of the earth.

The intensity of cosmic-ray showers was measured at each of the 1934 stations, using the vertical intensity at the same station as a standard for comparison. The following facts resulted from this investigation: (1) High-elevation (4300 meters) showers showed the same variations with latitude as pertain to the vertical rays, showing that the primary shower-producing radiation is also electrically charged; (2) sea-level showers showed less of a variation with latitude than the vertical rays, showing that shower-producing rays are less penetrating than the vertical radiation of the same magnetic rigidity; (3) shower intensities increased with elevation more rapidly than the vertical radiation, showing that the *average* shower-producing radiation is less penetrating than the average vertical radiation. (NOTE: Although some of the shower-rays are also vertical, they constitute but a small fraction of those thus classified. With the arrangement used for the shower-measurements, all but the shower-rays were automatically excluded.)

The asymmetry of the cosmic-ray showers was studied by means of three counters in an out-of-line configuration surmounted by a block of lead. The asymmetry found at 4300-meters elevation in Mexico was less than 2 per cent, compared with a 14 per cent asymmetry of the average radiation. The result is interpreted as indicating that the shower-producing primary

rays consist of positives and negatives in nearly equal numbers and, from their other characteristics, they seem to be positive and negative electrons.

When filtered by 10 cm. of lead, the asymmetry of the average cosmic radiation was less than that of the unfiltered radiation, indicating that the asymmetrical component is less penetrating than the background of symmetrically distributed radiation. This accords with the view that the unresolved background consists of higher-energy corpuscles, rather than of neutral rays such as photons, and it agrees with the experimental fact that the asymmetric rays diminish in intensity with depth in the atmosphere more rapidly than the symmetric background radiation.

Analysis of the variation of asymmetry with atmospheric path-length shows that the corpuscular intensity is absorbed according to an exponential law and is not characterized by a definite range, as experience with lower-energy corpuscular rays would have suggested. Although the absorption-coefficient undergoes a slight variation with energy of the radiation, the variation is not as great as a simple proportionality would require. Apparently most of the absorption of corpuscular rays of these energies (10 billion volts) is attributable to processes in which large fractions of the energy are given up at single collisions and the depth at which this happens is a matter of probability. Furthermore, the probability of such collisions depends only slightly upon the energy.

Further progress with the problems at hand requires (1) More accurate data regarding the variation of asymmetry with atmospheric path-length which would result in more accurate knowledge of the dependence of absorption probabilities on the energy. (2) A world survey of the asymmetry with particular emphasis on the variations of the asymmetry with longitude. (3) A world-survey of the intensity of the cosmic radiation from definite zenith-angles and azimuths. This is being attempted by means of automatic recording apparatus suitable for installation on shipboard. [The first voyage of this apparatus took place beginning August 10, 1935, on the Grace Line between New York and Valparaiso.] (4) More extensive studies of the intensities and angular distributions of the shower-radiation. Items (2) and (3) should result in a means of analysis of the earth's field at great distances from the surface and a clearing up of the apparent anomaly between the asymmetry and the latitude-variations at different longitudes.

Publications containing the principal results of the 1934 survey are listed in the Bibliography of this Year Book.

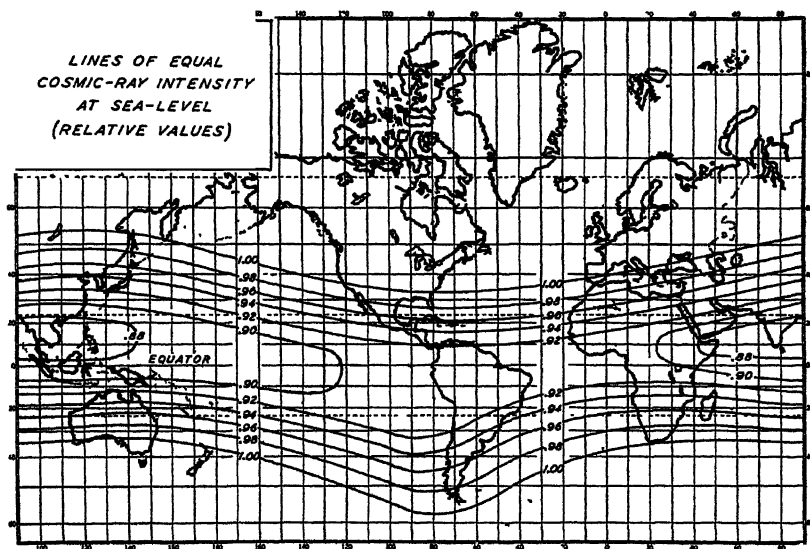
Dr. E. C. Stevenson assisted in the preparation of the instruments used in the survey. Mr. Lewis Fussell jr. cooperated in making the measurements and in reducing the data; Mr. Donald G. Follette also helped with the reductions. Professor M. S. Vallarta, Sr. R. Monges Lopez and Dr. C. S. Margain cooperated in making arrangements for the work in Mexico. Governor Solarzano of the State of Mexico placed at our disposal the facilities of living and communication on El Pico Nevado de Toluca. Transportation to the Nevado was supplied by the Secretario de Comunicaciones y Obras Publicas, and other agents of the Federal Government of Mexico gave their support to the work in that country. The work in Parral was facilitated by the generous cooperation of the American Smelting and Refining Com-

pany through the agency of Mr. M. N. Drury and Mr. A. A. Brown. On Mount Evans we were assisted by the trucking facilities of the City of Denver, arranged by Professor J. C. Stearns and Mr. D. D. Keim.

Millikan, Robert A., California Institute of Technology, Pasadena, California. *Studies of cosmic rays.* (For previous reports see Year Books Nos. 31-33.)

During the year from July 1, 1934, to June 30, 1935, the cosmic-ray work carried on at the California Institute of Technology with the aid of funds provided by the Carnegie Corporation of New York, administered by the Carnegie Institution of Washington, has consisted of the following seven projects:

(1) *Measurements made in connection with the Kepner-Stevens stratosphere flight on the precise shape of the ionization-altitude curve made with a self-recording Neher unshielded electroscope*—The most important result



of this flight has consisted in checking the conclusions reached a year earlier in connection with the Fordney-Settle flight made in the same magnetic latitude, namely, 52° north, that within the limits of our observational uncertainty the curve rises uniformly without any point of inflection or hump clear up to an altitude of about 60,000 feet. This result is of considerable importance for the theoretical interpretation of cosmic rays.

(2) *Measurements made with Neher recording electroscopes in three different airplane flights in Peru up to a maximum altitude of 28,000 feet*—These flights were supervised by Dr. S. A. Korff, and showed that in the equatorial belt up to the foregoing altitude the ionization-altitude curve is of the ex-

ponential form. The predominating component obtained from this curve shows an apparent absorption-coefficient of $\mu = 0.50$. The curve is in all respects similar to that obtained at March Field up to the same altitude in a similar way, save that the apparent absorption-coefficient at March Field was 0.55 instead of 0.50. This result also is of importance for the theoretical interpretation of the nature of cosmic rays.

(3) *Measurements on the equatorial longitude-effect in cosmic rays*—Self-recording Neher electrosopes have been sent within this year on the world-encircling cruise of the SS. *Franconia* covering a large portion of the Southern Hemisphere; on another world-encircling cruise of the Dollar Line SS. *President Hayes*; also on a cruise from Los Angeles to Sydney and return by the SS. *Monterey* of the Mattson line; and also on the SS. *Reina del Pacifico* sailing from Mollendo up the west coast of South America through the Panama Canal and on to Liverpool, then returning through the Atlantic Ocean around Cape Horn and back to Mollendo. The net result of all these operations has been to confirm completely the results announced a year earlier of the existence and the magnitude of the equatorial longitude effect, and to make possible a very much more reliable survey of the variation over the earth's surface of cosmic-ray sea-level intensities than has heretofore been available.

(4) *Another prolonged and accurate determination of the distribution of cosmic-ray energies as given at Pasadena by the vertical cloud-chamber method of Millikan and Anderson*—The net results of these studies made by Anderson and Neddemeyer may be summarized as follows: First, within the limits of observational uncertainty directly measured cosmic-ray energies in small numbers exist certainly up to more than six billion electron-volts, the estimates of the highest determinable energies being about ten billion electron-volts; second, within the limits of observational uncertainty positive and negative electrons appear in approximately equal amount in these cosmic-ray tracks, thus showing that the majority of these high-energy particles, in so far as they represent secondaries, arise from nuclear encounters; third, about 75 per cent of the single tracks represent energies under 4000 million electron-volts; fourth, that so far as can yet be determined all the secondaries produced by particle-encounters are low-energy secondaries, while in some cases, at least, secondaries produced by photon-encounters can rise to the value of several billion electron-volts; fifth, in the energy-range carefully investigated, namely in the neighborhood of 100 million electron-volts, electrons in shooting through heavy elements lose energy, (1st) by the usual ionization along the path, (2d) by close encounters with extranuclear electrons, (3d) by the occasional production of pairs, (4th) by the production of soft photons through close nuclear approaches. The first two effects are about equal and account between them for roughly half the total loss of energy of an electron traversing the atmosphere; the remaining half of the loss is practically all due to the 4th effect. Sixth, the number of secondary electron-tracks produced by close encounters of the high-energy primary electron with extranuclear electrons agrees satisfactorily as determined by direct experiments in lead and carbon with the number of such secondaries computed from theory.

(5) *Cosmic-ray counter studies*—Dr. Neher has succeeded in making modifications in the cosmic-ray counter techniques which promise to improve very considerably the resolving power of a cosmic-ray counter system, and make possible a more accurate study of the possible influence of celestial objects upon cosmic-ray intensities.

Mr. Pickering has obtained dependable results on the change in the character of the radiation as measured by counters in passing through a body of water some fifty feet thick, the so-called "shower-producing radiation" being more rapidly absorbed than is the radiation as measured by an electro-scope. This checks with experiments made by Rossi.

(6) *The development of a new and improved technique for measuring cosmic-ray ionization in the stratosphere*—Up to the present, all cosmic-ray stratosphere data coming from sounding-balloon ascents have been obtained from a single discharge of an electro-scope, the rate of discharge of which increases 200-fold in going from sea-level to say 70,000 feet. This means that only rough measurements on cosmic-ray intensities have been thus far made in the very high reaches of the atmosphere accessible only to sounding balloons. Doctors Bowen, Millikan, Neher, and Mr. Haynes have developed a new method of measuring cosmic-ray intensities, in which the electro-scope is charged up and discharged every five minutes, and seven or eight of these new instruments are now ready for service. No results of importance have yet been obtained by this method, but the promise of very great improvement in the accuracy of stratosphere measurements is now excellent.

(7) *Separation of cosmic-ray effects at the earth's surface from local radioactive effects*.—For a number of years, through the work of Doctors Millikan, Evans and Raitt, careful tests have been under way to determine whether cosmic rays induce softer secondary rays which radiating backward add their electro-scope-discharging effects to those of the radioactive constituents of the surrounding earth—a point of great importance for the determination of the magnitude of the cosmic rays at the earth's surface. This has involved the development of improved methods for measuring the uranium- and thorium-content of the rocks or other earths on which the cosmic-ray electro-scope stands. During the present year these long and important studies, partially supported by these cosmic-ray funds, have been completed with results indicating no appreciable amount of secondary cosmic-ray effects radiating upward.

The group of papers published during the year in connection with these researches will be found in the Bibliography.

Compton, Karl T., Massachusetts Institute of Technology, Cambridge, Massachusetts. *Research in high vacuum spectroscopy*. (For previous reports see Year Books Nos. 28-33.)

The vacuum spectrograph built with the aid of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington continues in service as a useful research instrument, and the following brief account of activities and of publications in this field is submitted.

USE OF THE SPECTROGRAPH IN RESEARCH

Dr. Charles A. Bradley, a National Research Fellow, continued his investigation of the extreme ultra-violet molecular spectra of deuterium and of ordinary hydrogen. He has obtained a number of good spectra of each, which have been measured in part. Dr. Bradley has now gone as a visiting fellow to the University of Michigan, taking his plates with him, and will there continue the analysis.

Dr. Andrew McKellar, another National Research Fellow, obtained plates of the extreme ultra-violet arc spectrum of oxygen. These plates are now awaiting measurement, but it is hoped that they will yield further information about the singlet system in OI, a matter of considerable astrophysical interest.

Mr. Walter Albertson used the vacuum spectrograph to extend to shorter wave-lengths the spectrum of cerium. Mr. Albertson has now gone as a National Research Fellow to the Mount Wilson Observatory, taking his plates with him. They will there be measured and analyzed as part of his general program of investigation of the spectra of the rare earths.

Mr. H. A. Robinson investigated the extreme ultra-violet spectra of phosphorus and has made considerable extensions and revisions in several stages of ionization of this atom. His results to date were summarized in a paper presented to the Washington meeting of the American Physical Society. The abstract of this paper has been published (*Phys. Rev.*, vol. 47, 799, 1935). Considerable progress has been made since the date of that meeting and a full paper will be submitted to the *Physical Review* in the near future. One definite result of this investigation is the possibility of exact prediction of the wave-lengths of nebular forbidden lines due to PII. As no lines of these wave-lengths have ever been observed in nebular spectra, the abundance of phosphorus in the nebulae must be quite low.

Mr. R. E. Evans photographed the extreme ultra-violet spectrum of a nickel spark and is still engaged in the reduction and analysis of his plates.

Continuing our policy of making the vacuum spectrograph available to duly qualified investigators from other institutions, three guests have made use of the instrument in the course of the past year. Mr. L. C. Green and Mr. C. W. Curtis, both Princeton graduate students working under Professor A. G. Shenstone, made brief visits to this laboratory and obtained spectrograms of iron and manganese, respectively, as excited in a hollow cathode. Dr. Carl A. Beck of the Catholic University of America is here at the time of writing and is engaged in an investigation of the extreme ultra-violet spark spectra of iodine.

PROGRESS IN ANALYSIS OF SPECTRA PREVIOUSLY RECORDED

While giving general supervision to the work of others using the spectrograph, Professor J. C. Boyce has continued his analysis of the extreme ultra-violet spectra of the rare gases. A progress report was given at the Washington meeting of the American Physical Society. The abstract of this report has been published (Phys. Rev., vol. 47, 799, 1935). In krypton, 138 new extreme ultra-violet lines of KrIII were identified in collaboration with Dr. C. J. Humphrey's analysis of the longer wave-length range of the third spectrum of this gas. One multiplet of KrIV has been identified. The results have been published in the Physical Review in separate papers by Dr. Humphreys and by Professor Boyce.

In argon the previous analysis, by de Bruin, of the second spectrum has been revised, and considerable extensions have been made in the third and fourth spectrum. Discovery of intersystem combinations in AIV has given definite proof of the identification of two nebular lines as due to forbidden transitions in this stage of ionization of argon. Results in AIII and in AV make it seem extremely likely that certain other nebular lines are also due to argon, but a definite announcement is withheld pending additional nebular observations. A detailed paper by Professor Boyce on the *Extreme Ultra-violet Spectra of Argon* has been accepted by the Physical Review for publication in September.

Measurements and reductions have been completed for one exposure of Xenon. Completion of the analysis will take some months and will require further measurements, but preliminary analysis to date has identified a number of the principal multiplets due to XeIII.

Incidental to the reduction of the spectra of the inert gases, previous wave-length standards were found inadequate in a certain wave-length range. Professor Boyce and Dr. C. A. Rieke have published in the Physical Review the values of new provisional standards for that region.

Dr. J. L. Nickerson, who was employed as an assistant under the grant during the year 1930-31, has published in the Physical Review a detailed discussion of some bands in the extreme ultra-violet spectrum of helium. The spectra in question were obtained that year, but difficulties of interpretation delayed the publication of the observations.

A list of publications issued during the year will be found in the Bibliography of this Year Book.

Committee on Study of Surface Features of the Moon. *Progress report for the period July 1934 to July 1935.* (For previous reports see Year Books Nos. 26-33.)

When Galileo in 1609 first examined the moon through his telescope, he was profoundly impressed by its surface features and concluded that a new world, not unlike the earth, was before him for study and exploration. Following his lead, astronomers have during the past three centuries examined and mapped the details of the moon's surface, and described and named its prominent formations. It is still true, however, that we do not know with certainty the exact nature of the lunar surface materials nor how any single surface feature on the moon was formed; nor has a map been prepared which is free from the personal equation of the observer. It was for the purpose of increasing knowledge in these fields that the Committee on Study of the Surface Features of the Moon was appointed.

The composition of the substances exposed at the surface of the moon can not be determined directly. The observer is unable to visit the moon and collect samples of its surface for laboratory test. He is therefore limited, in his attack on the problem, to the study of reflected light phenomena and to the determination of the changes which lunar surface materials produce on sun's rays on reflection. Comparison of these changes with the effects which terrestrial materials have on sun's rays on reflection enables him to classify the materials and to ascertain the kinds of terrestrial substances which resemble lunar materials most closely. It is well known that the accuracy obtainable by methods of reflected light is not so great as that with transmitted light; but in this case the observer has no choice but to make the measurements as accurately as possible and by several different methods.

The changes produced in sun's rays on reflection by solids are of two kinds: (a) A certain amount of plane polarization is introduced, depending on the nature of the material, on the character of its surface, on the wave-length of the incident radiation, and on the angle between the incident and the outgoing beams (phase angle); (b) the relative intensities of radiations of different wave-lengths are changed somewhat on reflection (selective reflection).

Four independent methods are being used for ascertaining the percentage plane polarization in sunlight reflected by different parts of the moon's surface; (a) a visual method for which a special eyepiece is required; three other methods, based, respectively, on the use of (b) an ultra-violet polarization spectrograph, (c) a photoelectric cell combined with a large Wollaston prism of quartz, and (d) a vacuum thermoelement. During the past year, pending the construction of the new mounting for the 20-inch telescope, only the visual method has been employed in an effort to complete the series of visual measures, both on lunar areas and on terrestrial materials illuminated by sun's rays. The new mounting for the 20-inch telescope will not be finished before 1936; after its completion, measurements with the three non-visual methods will be resumed.

The visual measurements have been carried through seven lunations on 24 selected lunar areas. In addition many determinations of percentage

plane polarization have been made on terrestrial materials illuminated by sun's rays. For this purpose the eyepiece employed in lunar observations has served well for the determination of polarizations not exceeding 26 per cent. For the measurement of higher percentages a second eyepiece was adopted. In it the detector system of the first is retained; but in place of the tilting compensator a combination of two Rochon prisms, a compound Wollaston prism, and a rotatable Thompson prism serves to compensate the polarization in an incoming beam.

Observations on terrestrial materials have shown that the amount of polarization introduced on reflection from non-polished surfaces depends not only on the nature of the material under examination and on the phase angle, but also on the nature of the surface itself. Measurements were made on rough fracture surfaces of rock specimens, on flat surfaces rough ground with 150-mesh carborundum, and on powdered specimens of different average grain sizes. Under these conditions the incident light is in part absorbed and reradiated as heat; in part it is reflected, either directly or after repeated refractions, by the small cleavage faces and fracture facets of the different component minerals; in part it is diffracted and scattered by the uneven surfaces. Under these conditions the outgoing beam is not the simple reflected beam considered in the Fresnel theory of reflection and refraction. Analysis of the data of measurement thus far obtained has thrown light on the phenomena of plane polarization introduced under these conditions; especially on the significance of negative polarization in which the plane of vibration of the outgoing beam is parallel with the plane of incidence, and not normal to it as it should be on the basis of the Fresnel theory of reflection from flat polished surfaces. Polarization measurements on moon beams showed that negative polarization begins at phase angles near 158° ; it increases to an average maximum of 1 per cent and then decreases to zero at 180° ; beyond this the curve is repeated and crosses to positive polarization at the phase angle near 202° . Terrestrial materials exhibit a greater range of limits; and also of percentage amounts of negative plane polarization; on certain substances negative polarization is practically absent; on other kinds of material the limits may reach the phase angle limits, 125° and 225° . A laboratory investigation into the causes of negative polarization is in progress; the phenomenon has greater theoretical than practical diagnostic interest.

A preliminary study has been made of the relative frequency of lunar craters of different diameters, as listed in the publication entitled "Named Lunar Formations" by M. A. Blagg and K. Mueller, International Astronomical Union, 1935. The total number of craters, for which the diameters are given, is approximately 3950, not including 35 small confluent craters. The analysis shows that the distribution curve is remarkably smooth and approximately exponential in character. A similar grouping and analysis of terrestrial craters is in progress but the data are relatively few in number and are less accessible than the lunar data. No satisfactory explanation has been found for the roughly exponential character of the frequency distribution curve found for lunar craters.

The results obtained by projecting negatives of the moon on large globes coated with photographic emulsion, as described in last year's report, were

not entirely satisfactory; the coating proved to be too thin and the developer employed failed to give the desired contrast. Accordingly the globes have been recoated with thicker film by the Research Laboratories of the Eastman Kodak Company and are to be rephotographed in the near future. On these globes the surface features of the moon are represented without distortion and as they appear on the moon. They are angle-true, miniature moons and will be of aid to the Committee in its study of the physiography of the moon. The coating of the globes marks a step forward in photographic technique, and credit for it is due entirely to the Research Laboratories of the Eastman Kodak Company.

Refiguring of the zero corrector lens of the 100-inch telescope during the past year has prevented the taking of moon photographs for map purposes. It is planned to use this lens in 1936 for lunar photography, if seeing conditions prove to be favorable.

Visual observation and study of the surface features of the moon have been continued by Doctors Adams, Pease, and Wright.

Committee on Study of Surface Features of the Moon.

W. S. ADAMS,
J. P. BUWALDA,
A. L. DAY,
P. S. EPSTEIN,
F. G. PEASE,
E. PETTIT,
H. N. RUSSELL,
F. E. WRIGHT, *Chairman*.

PHYSIOGRAPHY

Sykes, Godfrey, Tucson, Arizona. *Continuation of Study of the Colorado Delta and the Lower Colorado River.* (For previous reports see Year Books Nos. 29, 31, 32.)

The study of the lower Colorado and the Delta has developed along two lines during the past twelve months. These may be briefly summarized as follows.

FIRST—Observation of the processes of the increasing desiccation and arrested development in the recently active areas in the sub-aerial portion of the delta, which have been brought about by the diminished river discharge and the restriction of the supply of detrital matter; and further observations upon the associated changes in the estuary and tidal-channels, due to the same causes.

SECOND—The investigation of problems which have arisen, relative to the changing character and renewed partial movement toward the areas of deposition in the delta, of the vast body of bed-silt which underlies the river channel between the foot of the Canyon section and the mouth of the Gila. This development appears to be directly due to the retention, in the great new storage reservoir above the Boulder Dam, of practically all the supply of detritus which has hitherto kept the channel in a state of equilibrium and stabilization. Especial attention has been devoted to this phase of the general study during recent months, owing to the fact that heavy psammitic deposits, which are now invading the canals of the several irrigation enterprises along the course of the lower river and in the delta, and which are the cause of great anxiety and expense to the executives of the various projects, can be traced with reasonable assurance to the erosion and disintegration of the river bed between the Dam and the canal intakes.

The progress of desiccation of the delta, as revealed by numerous examinations of the region which has for so long been subjected to periodical inundations, is not spectacular, but is nevertheless slow, sure, and relentless. Soil moisture, although obviously failing, still remains in sufficient quantity to benefit the more deeply rooted trees and larger shrubs, but areas which were formerly covered with dense stands of various forms of hydrophytic vegetation are now bare, or becoming increasingly so as the less resistant species succumb.

It must be remembered that the annual precipitation in this and the surrounding regions is less than three inches, and that vegetal growth is almost entirely dependent upon soil or surface moisture.

Previous instances have been observed, as when the river made its great excursion to the western side of the delta in 1909, when plant-life over extensive regions would undergo change, and pre-existing forms were replaced by others better adapted to the altered conditions and environment. At the present time, however, the development is toward elimination rather than

substitution, with the exception of along a narrow zone bordering the course of the single controlled stream which reaches tide-water at the present time.

The general effect of the recent great reduction in the amount of detritus reaching the delta has been a tendency toward the simplification and deepening of this waterway, thus reducing the probability of trans-riparian overflow and lateral inundation during periods of increased discharge. Areas favorable for the continued growth of vegetation are therefore likely to be still further restricted, even along its meander belt.

Within the tidal zone, the observed effects of the diminished quantities of water and detritus entering it from the river have been the increased salinity of the water in the tidal reaches and the continued process of depletion of shoals and bars in the estuary.

The most important event which has occurred during the year, as a determining factor in the present and future condition of the lower river and the delta, has been the practical completion and closure of the Boulder Dam and the consequent inception of the process of impounding and storing the water for the purposes of conservation and flood control. It has already been possible to accumulate a sufficient body of water above the barrier to bring about radical changes in that which is released from the by-pass for use in the irrigation districts below. Practically all of the great burden of detrital matter which the river carries into the Grand Canyon is retained in the eighty-mile lake which now occupies the lower gorges and the controlled and regulated stream which issues below the dam is comparatively clear. Before the head of the delta is reached, however, the clarified water is found to have again picked up an appreciable load from the river-bed, which it carries forward both in suspension, as evidenced by renewed turbidity, and also by the more obscure and less clearly understood methods of saltation and traction.

As it was anticipated, before the dam was completed and the process of storage began, that disintegration and erosion of the deposited body of detritus which forms the bed of the channel below would take place when it was subjected to the scouring effect of a stream of desilted water, advantage was taken of the exceedingly low condition of the river during the Winter months to secure a series of samples taken from the surface and subsurface layers in typical channel sections, which might be used for purposes of comparison with other series to be taken later, and after the scouring process had come into operation.

The later series although still incomplete, owing to the impossibility of obtaining the required number of samples from the thalweg of the channel in the present stage of the river, is now undergoing examination and mechanical analysis already in accordance with a pre-determined method of procedure. The results obtained are of great interest both in their bearing upon the rather obscure matter of the movement of bed-silt material in general, and upon their more particular application to the problems incidental to the deposition of this final contribution of the Colorado to the body of its delta.

The complexity of the problem under investigation has hinged largely upon the fact that due, first, to the character of the material of which the detrital load carried by the Colorado is composed, and, second, to the process of at-

trition to which that passing through the rapids and sluice-ways of the Canyons is subjected, that which has issued from their lower ends, and now forms the river-bed through the valleys below, has been reduced to a state of almost uniform fineness which is very close to the critical point at which it ceases to be sand and becomes silt; or, stated in another way, at which it has become sufficiently fine to remain suspended in the flowing stream at all ordinary current speeds, and so is not deposited as long as the water continues in motion.

The desilted water now issuing from the dam, which may be considered as existing in a condition akin to the "nascent" state of the chemist, in so far as its capacity to acquire and transport a further loading of finely divided detritus is concerned, appears at the present time to be attacking the river-bed in a selective manner, by first leaching out and removing in suspension the finer components of the surface layers, and leaving for slower transportation toward the delta and gulf a coarser or psammitic residue, with grains of approximately uniform size, which, under certain conditions of current and opportunity for free passage through the thalweg of the channel, becomes exceedingly mobile and is transported by saltation, traction, or other means, in sufficiently great quantities to have already become a serious menace to the carrying capacity of several of the large irrigation canals in the Imperial Valley and the delta.

At the present time, both the coarser and finer components which are being eroded from the river-bed between the dam and the delta are passing through the latter quite freely, and are only finding lodgment in the estuary or are being carried directly to the sea. This is in consequence of the development of the main drainage channel alluded to above, which has adapted itself to the passage of the present controlled discharge from the Boulder Dam and to the detrital load which it is now acquiring and transporting.

PHYSIOLOGY

Duel, Arthur B., New York City, N. Y. *A study of spasm or tic occurring in facial muscles recovering from facial palsy.*

A little more than six years ago Sir Charles Ballance and I began experimentation at my country place to improve the operation for surgical repair of the facial nerve.¹ At the end of a year, we had demonstrated the possibility of direct line restoration of the nerve by means of auto-plastic nerve grafts.

In some of the recovering cases there occurred a tic, or muscle spasm, of groups of facial muscles, similar to that which occur in humans in partially recovered cases of Bell's Palsy of the severer type. Most of these tics occurred in large baboons who had only been observed at a distance in their large cages, owing to the difficulty in capturing and anesthetizing them after their operations.

At their final capture for sacrifice and study by stimulation intracranially and peripherally, and for the purpose of securing specimens for microscopic examination, Sir Charles made the observations of the tic while the animals were under light anesthesia. The specimens of the cortical area were secured for examination just before the animal's sacrifice.

At a later date more recent specimens of facial cortex, in which the facial nerve had been severed on that side for varying periods, were sent to him at the Royal College of Surgeons of England, for comparison with the corresponding area on the other side, on which the facial nerve had not been severed. His conclusions will be found in "A Note on the Large Pyramidal Cell of the Facial Area of the Left Rolandic Cortex."

Changes in the cortical cells were found, and to these and to possible changes in the facial nucleus in the medulla were attributed the incomplete recovery of the facial movements and the tic.

In the meantime I had become deeply engrossed in the use of graft material from the anterior femoral cutaneous nerve, which had been previously degenerated *in situ* (by severing the nerve and allowing it to remain in position for two or three weeks).

In order to properly observe results, the animals had to be captured and examined almost daily for from one to two months. I, therefore, used small rhesus monkeys since they could be easily captured and examined without anesthesia. The use of the degenerated nerve proved to be a great success, accomplishing a return of facial movements in a much shorter time than previous methods of freshly excised grafts.²

To my amazement, however, the constant observation of the recovering cases revealed the fact that, in every instance, at about the time when conjunctival reflex appeared, a tic, or spasm, in certain groups of muscles

¹ *The Operative Treatment of Facial Palsy*, Jan. 1932.

² *History and Development of the Surgical Treatment of Facial Palsy*, Surgery, Gynecology and Obstetrics, Feb. 15, 1933.

occurred. These were greatly exaggerated by the emotional excitement of capture, stimulation by Faradic current, threat or conjunctival irritation. A most animated correspondence between Sir Charles and myself followed, I contending the defect must be peripheral; he that it must be central. I removed the cortical facial area in an animal having a tic which had appeared during recovery from an induced facial palsy which had been repaired by an autoplasmic graft. The animal lived for more than two years; the tic continued quite unabated. I removed the cortical facial areas in three monkeys—right, left, both sides. The animals recovered, having lost voluntary control of the facial muscles involved, but with perfect emotional and reflex control.

Induced facial palsies in each were subsequently repaired by autoplasmic grafts. At the same stage of recovery in each a tic appeared. A series of experiments was done on cases of induced Bell's Palsy by alcohol injection, and freezing, for the purpose of evaluating the decompression of the nerve, in severe cases as to improvement in amount of recovery or shortening of time. They all answered the question. Forty of the forty-two in the course of their recovery developed a tic!

Having eliminated the cortical change as a cause, I enthusiastically read a theoretical paper before the American Otological Society¹ in which I postulated that the cause of the tic was peripheral rather than central, and predicted that it would be proven to be so.

However, I must hasten to say that my theoretical conjecture as to the pathology was not accurate, although the lesion was proven to be peripheral.

At any rate at this juncture the Carnegie Corporation generously made us a grant to be administered through the Carnegie Institution of Washington, for further study of the problem.

With the able assistance of Dr. Edmund P. Fowler jr., of New York, we began an investigation to determine whether the lesions of the peripheral end of the facial nerve produced definite changes in the facial nucleus in the medulla, or in the facial area of the cortex in the brain. Sufficient to say that in all our experiments, we have not been able to demonstrate any changes which we did not feel were due to artifacts. An ingenious suggestion by Dr. Fowler, in which the peripheral branches were switched, eventually aided much in the solution of the problem and strongly substantiated the final physiological solution, the details of which appear in the report.

At this stage of our progress Dr. Lewis H. Weed of Johns Hopkins spent a few days in going over our animals, and at the end sent to us, from his Anatomical Department, Doctor Sarah Tower and Doctor Howard A. Howe, who made a series of experiments which gave us a definite answer to our problem.

There were available at that time forty-two operated monkeys; of these thirty-five were selected. They represented facial tics resulting from several types of operations and involving many different groups of muscles. Under ether anæsthesia a branch of the facial nerve going to a muscle involved in the tic was exposed close to its entrance into the muscle, doubly ligated, and cut. The two ends of the nerve were then stimulated. A corresponding

¹ *Study of Muscle Spasm Occurring During Recovery from Facial Palsy*, Trans. American Otological Society, 1933.

preparation was made on the normal side. On both sides, stimulation of the distal cut end of the nerve provoked contraction of the muscle supplied, and of this, only. Stimulation of the central cut end produced on the normal side no reaction, or feeble contraction in an immediately adjacent muscle mass. On the side of operation, stimulation of the central cut end produced contraction in far distant parts, and in several instances in the entire facial musculature. Section of the facial nerve either at its exit from the medulla, or in the facial canal, modified these responses not at all. These findings indicate that the mechanism for spreading the reaction is entirely in the periphery, and can be explained only on the basis of a large number of split axones in the facial nerve. The stimulus applied to the central end of a nerve branch thus travels back antidromically on an axone until it reaches a point of bifurcation. There it is distributed to all other muscles which happen to be supplied by the particular split axone in question. This division of axones into many branches is a feature of normal growth, and especially of regenerative growth after nerve injury. In the intact animal the branches of any given axone are restricted in distribution to immediately adjacent muscle masses, but when the trunk of the facial nerve is cut conditions are provided in the neuroma formed at the site of injury for branches of the same axone to grow out into widely separated parts of the total facial field, and perhaps to be distributed throughout the entire facial musculature.

The final answer, as will be seen from a study of the long report, is that the tic occurring in recovering facial palsies in monkeys is due to a splitting of the axones in the peripheral branches. Once established, this tic shows no sign of regression.

By analogy, it may be assumed that the facial spasm occurring in partially recovered facial palsies is due to a similar splitting of the peripheral axones. Under these circumstances, it is probable that these facial spasms can not be cured by operative interference. There is much room for further study from the anatomical standpoint.

Hartman, Frank A., University of Buffalo, Buffalo, New York, and Ohio State University, Columbus, Ohio. *Studies on cortin and the adrenal cortex.* (For previous reports see Year Books Nos. 31-33.)

The studies on cortin and the adrenal cortex are being continued through the support of an appropriation by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Work on the relation of cortical extract to vitamin C deprivation has been repeated, with the collaboration of J. E. Lockwood and D. R. Swan. The extract used contained less than one-tenth of the protective dose of vitamin C (iodine titration method). The results agree with those previously reported, *viz.* cortin containing extracts delay the onset of scurvy.

Cortin plays an important rôle in the maintenance of plasma volume. Without it the latter is reduced. Work carried out in collaboration with C. A. Winter indicates that this is neither explained by loss of fluid through the kidneys nor by decreased intake. Water balance in adrenal insufficiency

in cats is negative and becomes positive during the recovery period. These results can be duplicated by gradually reducing the food intake in normal animals without producing symptoms. There must be a redistribution of water in the body of cortin insufficient animals. How this is produced is unanswered, but we know that sodium and chloride escape in abnormal amounts through the kidneys. This leads to a shift of electrolytes in the body. Although these losses may be significant, there are other changes more fundamental, for it is sometimes possible to bring about recovery from collapse by the injection of cortin without the additional administration of water and electrolytes. While an increased intake of sodium chloride ameliorates the symptoms of early adrenal insufficiency, it is unavailing in the late stage.

Doctor Winter has shown that diet has an effect on the water inhibition of muscle. Therefore in studies on adrenalectomized animals, this factor must be controlled.

The effect of cortin upon the experimental neurosis in sheep (with H. S. Liddell, O. D. Anderson and E. Kotyuka) has been completed and is in press.

A definite and enduring nervous disturbance or neurosis, characterized chiefly by extreme excitement, uncooperative behavior and by spontaneous, nervous, twitching movements was produced.

The administration of an extract of the adrenal cortex, containing cortin, to animals in this condition, was found to increase the vigor of the conditioned reaction of the limb to a great extent and at the same time to decrease the frequency of the nervous leg movements. The animals became more quiet.

The conditioned reflex in normal sheep was also found to increase in vigor during the administration of the extract. The results with cortin in sheep bear out those on the human being.

The repeated administration of adrenalin in a concentration of 1:200,000 was observed to have an effect upon behavior exactly the opposite to that of cortin. Adrenalin decreased the vigor of the conditioned reflex in both normal and neurotic animals, and in the latter it aggravated the nervous condition.

When cortin, relatively free from epinephrin, was administered, the beneficial effects were greater and cumulative. Moreover they persisted for more than twenty-four days after the last injection.

Students of adrenal physiology have sought for years to produce chronic adrenal insufficiency experimentally. This can best be done by the administration of inadequate doses of cortin in adrenalectomized animals. After observing many animals with chronic insufficiency so produced, we conclude that failure of appetite and increased fatigability are the earliest symptoms to develop. The picture presented in chronic adrenal insufficiency is not greatly different from that observed in adrenalectomized animals during their normal survival period without cortin.

Chemical studies in which the potency of the extract has been assayed on adrenalectomized cats have led to the following conclusions.

Alcohol is the best solvent for extracting the tissue. Neither acetone nor benzene are as effective. If, however, one extracts whole glands, it is neces-

sary to pass the hormone through a solvent like benzene in order to remove toxic substances taken up from the medulla.

In removal of the solvents, if the volume is reduced too far there is a decided loss in potency.

The following assistants have been employed either full time or part time during the past year: W. W. Hammersley, W. D. Pohle, M. D. Rogick, D. R. Swan and C. A. Winter.

Papers, not previously reported, will be found in the Bibliography of this Year Book.

PSYCHOLOGY

Ruger, Henry A., Teachers College, Columbia University, New York, N. Y.
Studies on the theory of surfaces. (For previous reports see Year Books
Nos. 27, 29-33.)

These studies have been continued with funds made available by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The Frequency Surface Research has been concerned mainly, during the last year, with the further reduction of Sir Francis Galton's measurements on 7000 males of ages from 6 to 82 years. Three studies based on these data had already appeared as follows:

- (1) *Annals of Eugenics*, vol. II, pages 76-110, On the Growth Curves of Certain Characters in Man.
- (2) *Annals of Eugenics*, vol. V, pages 59-104, On the Interrelationship of Certain Characters in Man.
- (3) *Annals of Eugenics*, vol. V, pages 364-412, also entitled "On the Interrelationship of Certain Characters in Man."

The first of these presented life curves for central tendencies and variabilities for fourteen human traits. These might be classed as anatomical, motor and perceptual. The second and third papers dealt with the interrelations and intrarelations of the first two of these classes. The data employed in the two Interrelationship studies had previously been corrected for age differences by treatment of them as residuals from their curvilinear trend lines and correction of them for differences in variability. The second and third studies presented the variances, covariances, correlation coefficients and ratios, regression coefficients, equations and lines, both for the total population of 7000 and for the separate populations of the 28 age groups. Despite the age correction for the eight traits involved, some of the measures of relationship showed secular trends. In the neighborhood of 5000 frequency constants were presented in this connection.

The work of the current year has been the extension of this treatment to what may be called the higher covariances, or higher product moment coefficients. These coefficients are those involving a total exponent of eight or less, 27 for each pair of traits. These coefficients have all been computed and are now being rechecked. The relationship of each of these constants in the total and partial populations will be studied next. These results will be used in the interpretation of tests of linearity and other characteristics of frequency surfaces. Competent statistical assistance has been furnished by E.R.A., E.R.B. and W.P.A. in the services of Kurt von Brand, Antonia von Brand, and Ivan Rosov.

SEISMOLOGY

REPORT OF THE ADVISORY COMMITTEE

(FOR PREVIOUS REPORTS SEE YEAR BOOKS NOS. 20-33)

COLLABORATION WITH THE U. S. COAST AND GEODETIC SURVEY ¹

The investigation of nearby earthquakes, which was begun by the Advisory Committee in Seismology of the Carnegie Institution of Washington, has stimulated interest in other phases of earthquake study. Engineers have stressed the need for studies which will result in better design of buildings and other structures to resist earthquakes. During the fiscal year ending June 30, 1935, Public Works funds were provided, which made possible the study of vibration periods of buildings and other structures and of the ground. The plan of work was developed at a series of conferences, attended by engineers, architects and seismologists, several of which were held at the Seismological Laboratory.

Vibration measurements have now been made in two hundred and twelve buildings, on thirty-seven elevated water tanks, on one completed and two incomplete bridges, two dams, six pavement sites, and on several structures of special design. Through the loan of several Wood-Anderson seismometers by the Seismological Laboratory, this work was started at a much earlier date than would otherwise have been possible. These were modified for this work immediately following the Long Beach earthquake.

Facilities for the work were greatly improved when the Coast and Geodetic Survey developed a so-called vibration meter which utilized the general principle of the Wood-Anderson seismometer especially adapted to vibration measurements. The provision of several different suspensions made it readily possible to suit the instrument to a particular requirement.

Present instruments are rather awkward for simultaneous vibration measurements in different parts of buildings or other structures. There is need for an instrument with four readily portable seismometers connected to galvanometers which record on a single drum. An apparatus which possesses this and many other advantages has been partly completed at the Seismological Laboratory with Coast and Geodetic Survey personnel and equipment under the direction and in accordance with the design of Dr. Benioff (p. 366). This instrument is expected to be especially useful in recording strong after-shocks of earthquakes in buildings.

The measurement of ground periods by explosion or by shaking machine has been done to only a limited degree in California. The first comprehensive attack on the problem of ground periods has been the investigation at the Seismological Laboratory under the direction of Dr. Gutenberg of several thousand seismograms. These are from the five associated stations. The personnel employed in the measurement of the seismograms was provided by the Coast and Geodetic Survey.

¹ From information furnished by Capt. N. H. Heck, Chief of the Division of Terrestrial Magnetism and Seismology, U. S. Coast and Geodetic Survey.

In the strong-motion work begun by the U. S. Coast and Geodetic Survey in 1932, instruments have been operated throughout the length of California. Twenty-five records of nine earthquakes were obtained during the present year. In all earthquakes in the southern part of the state, the value of the records was enhanced by exact knowledge of the position of the foci, furnished by the Seismological Laboratory.

The principal data accumulated during the year will be summarized in one volume to be published by the Coast and Geodetic Survey. Among the authors are Beno Gutenberg of California Institute of Technology and Hugo Benioff of the Seismological Laboratory.

One phase of the work in a purely engineering field was a study of damage to buildings at Long Beach and adjacent towns. The work was under the direction of R. R. Martel, his party being provided by the Coast and Geodetic Survey.

It might be mentioned that a Wood-Anderson seismograph loaned by the Seismological Laboratory for temporary use at the Coast and Geodetic Survey at Sitka, Alaska, was brought to Washington for comparative tests, along with other instruments of high sensitivity, upon a shaking table at the Bureau of Standards. These tests of comparative behavior under like measured conditions will have general interest.

One other activity that has been going on for a number of years is the collection of reports of visible and felt effects of earthquakes by volunteer observers in the west-coast region. This was originally carried on by the Seismological Laboratory for the southern half of California, but later the work was taken over by the Coast and Geodetic Survey.

GEODETIC WORK IN REGIONS OF SEISMIC ACTIVITY ¹

The Coast and Geodetic Survey during the fiscal year ending June 30, 1935, has been actively engaged in extending the horizontal and vertical control nets over the country. More than a hundred thousand miles of first- and second-order leveling were added to the vertical control survey net, making an approximate total of 250,000 miles in the country. About 17,500 miles of first- and second-order triangulation were also added to the horizontal control net in the same period.

Work that is of special interest to seismology consists of three arcs of triangulation in California, totaling 300 miles in length. These three arcs are one along the Mexican boundary from El Centro to San Diego, another from Lucerne Valley to Needles, and the third from Rice to Kingston.

A very intensive leveling survey was made at the request of the Chairman of the Advisory Committee in Seismology of the Carnegie Institution of Washington. It includes eight lines of closely spaced bench marks, approximately normal to various known fault lines in southern California. A number of these lines cross San Andreas fault in the vicinity of Maricopa, Bailey's Ranch, Palmdale, Cajon and Whitewater. Another line crosses the double San Jacinto fault in the vicinity of Armada. There is a line across the Whittier fault in the vicinity of Brea, and one across the Inglewood fault

¹ From information furnished by Major William Bowie, Chief of the Division of Geodesy, U. S. Coast and Geodetic Survey.

at Inglewood. Each of these lines extends for about five miles out from the fault in either direction. Bench marks were spaced at intervals of 100 feet for the first mile, at 200 feet for the second mile, 300 feet for the third mile, 400 feet for the fourth mile, and 500 feet for the fifth mile. This spacing was decided upon by the Advisory Committee in Seismology.

A year or more ago a network of lines of levels in the vicinity of San Jose, California, involving more than 200 miles of leveling, was established with a view to studying the reported subsidence of the area. This net was rerun in the autumn of 1934 and in the spring of 1935. It has not been possible to compute and adjust the work done in those two periods, but reports from the chiefs of the leveling party which carried on the field work indicate that the subsidence noticed in previous leveling is continuing. It is hoped that within a few months it will be possible to make the computations and adjustments of all the leveling in the vicinity of San Jose.

THE SEISMOLOGICAL LABORATORY¹

The regular work of the program has gone on through the year, very satisfactorily, and good progress has been made in reducing the arrears of measurement mentioned in previous reports. The purpose and importance of this work, routine in nature but of high scientific import, has been stressed in numerous earlier reports and need not be repeated here. As before, the burden of this work has been heavy and in consequence not much new work has been undertaken, aside from the research studies. The interpretation and measurement of the seismograms in regular course, and the preparation and circulation of mimeographed reports upon the results, have been carried on throughout the year.

EARTHQUAKE ACTIVITY²

Activity in the region immediately under survey remains much as described for previous years. The faults and localities from which we have been accustomed to record minor shocks still continue active. An exception is the continuing absence of shocks from the area in the Mojave desert, which was very active in 1929-32. The local shock activity about Santa Barbara has now decreased so much that it is actually less than the activity near some of the other stations; so that the aftershock period of the Santa Barbara earthquake appears definitely to have closed. The same probably can not be said for the Long Beach earthquake, as small shocks along the active segment of the Inglewood fault still are a large fraction of those occurring in the Los Angeles region.

At slightly greater distances from Pasadena, more definite changes in activity have taken place. The aftershocks of the Parkfield shock of June 7, 1934, appear to have been less numerous than those of the other shocks mentioned, even making due allowance for the greater distance of our stations from the source. Their occurrence affected the general pattern of activity for only two or three months. During September there was a considerable group of moderate shocks in the Nevada region, but since that time even the

¹ Extracted from the Annual Report of H. O. Wood, Research Associate in Seismology.

² Dr. C. F. Richter.

Nevada shocks have ceased to form a considerable fraction of shocks recorded at Pasadena.

An important seismic event took place at the close of 1934. During November there was considerable activity just south of the Mexican boundary, one of the shocks, on November 25, reaching magnitude 5. More of these shocks, of magnitudes up to 3.5, occurred in the first weeks of December; and on December 30 at 5:52 a.m. there was a shock of approximate magnitude 6.2, with numerous aftershocks which were interrupted by a still larger earthquake (magnitude about 6.5) on December 31 at 10:45 a.m. Further aftershocks continued during the following months; one on February 23 reached magnitude 6.0.

For the largest shock, on December 31, reports have been received from most of the stations of the world; and as the shock was large enough to give clear records in America, Europe and eastern Asia, a large body of data is available for determining the epicenter and origin time. The experience and results gained by the study of seismograms at large distances have been of much value in this work.

The three large shocks mentioned—those of December 30, December 31, and February 23—had a common epicenter at about $31^{\circ} 48' \text{ N.}$, $115^{\circ} 12' \text{ W.}$, with a probable error of about $2'$ in either coordinate. This location is at the eastern edge of the mountains of the Peninsular Ranges which lie west of the head of the Gulf of California. The area shows fresh scarps and other indications of geologically recent activity.

This same epicentral region has been a frequent source of earthquakes since the time when it was first possible to make locations from our stations, beginning late in 1926. Particularly large shocks of this group occurred on October 5, 1927, and on September 30 and October 9, 1931; but none of these approached the recent shocks in magnitude. The shock of December 30, 1934, caused fissuring and slumping in the deep and water-soaked alluvium of the Colorado delta south of the international boundary, with consequent damage to weak structures, including the fall of a water tank. It was felt in the United States only in the southern counties of California and a small part of Arizona; early press reports which indicated a larger area of perceptibility in California were misleading, due to the occurrence of a sharp shock in the San Francisco Bay region about three minutes later which was felt over a separate area. The still larger shock of December 31 caused serious damage to railroad lines and bridges in Mexican territory, and minor damage to a few weak structures in California and Arizona. It was perceptible over a large area, including points in the San Joaquin Valley in California and Prescott in northern Arizona. At most points in southern Arizona, it was described as the strongest earthquake in many years. At Los Angeles numerous persons were alarmed by the long duration of perceptible shaking, which, owing to the considerable distance, exceeded two minutes, estimates being further extended by the continued oscillations of chandeliers, etc.

The two large shocks were well recorded on practically all our instruments, including the strong-motion instrument at Pasadena. Our records are particularly valuable on this occasion, since this epicentral region is unfavorably

situated for location from our stations alone, while in this case the registration at distant stations facilitated good location and thus permitted confident interpretation of the phases recorded by our instruments, so that future shocks in this region will be much better understood.

The epicenter given above is not the only point of recent vigorous activity south of the international boundary. That of November 25, mentioned above, originated much farther west, near the west coast of the peninsula of Lower California. On April 29 a shock of about the same magnitude (5) occurred, which was instrumentally located in the same area, not far from Ensenada.

Except for these disturbances in Mexican territory, the first five months of 1935 were an unusually quiet period in our area. A more normal number of shocks was recorded after June 1.

Other shocks which deserve special mention were: that of December 17, 1934 (magnitude 4.5), which occasioned minor damage at Los Alamos, Santa Barbara County; a considerable number of small shocks (the largest of magnitude 3.5) on May 10, 1935, and following days, in the upper Kern River region, with a larger shock on June 11; several shocks, mostly during April 1935, near Ventura; and a shock of magnitude 3, on March 7, 1935, at 7:18 p.m., which originated on the San Andreas (or possibly San Jacinto) fault near Valyermo. The last-mentioned shock is almost the first to be positively located on either of these faults between the Cajon Pass region and Tejon Pass during the present program, although there have been one or two doubtful cases previously. In the present instance there is no room for doubt, as the shock was reported felt at Llano, on the desert just to the North. The inactivity of this segment of the San Andreas Rift, even for very small shocks, has been the most striking feature of our instrumental regional study beginning about 1926—contrasted as it is with unquestionable activity along the Rift northwest and southeast of the limits indicated. On July 6, 1934, a shock of magnitude 6 occurred off the Oregon coast.

Increasing experience has led to increased care in issuing monthly bulletins of teleseisms, resulting in the inclusion of a larger number of shocks. Five hundred and seventy-eight teleseisms were listed for the eleven months June 1934 to April 1935, inclusive. Most of these were small, but in nearly all cases the report gives the time of the first, or P, wave, and this datum frequently proves of value in locating shocks. Comparison with reports received shows that of 127 teleseisms during November and December, 83 were recorded at one or more stations outside California, while several important stations have not yet reported.

Very few teleseisms wrote large records at Pasadena in the interval here considered. On July 18, 1934, a considerable shock in Panama was recorded, followed by numerous aftershocks on the following days, during which there also occurred two large shocks in the South Pacific. Thereafter, no large seismograms were written until November 30, when there was a large shock off the west coast of Mexico. A much smaller earthquake on December 2 caused considerable damage in the interior of Honduras and was the subject of numerous and probably exaggerated press notices. On April 19, 1935, a shock occurred in the Mediterranean off Tripoli. Although this was the

largest shock in the European region for several years, and practically the first of such to write good seismograms at Pasadena, it attracted very little attention hereabouts. This perhaps was due in part to the occurrence of a destructive shock in Formosa on the following day. As these two earthquakes were at nearly the same distance from Pasadena, it is possible to state that the European shock appeared much the larger.

The only truly great earthquake recorded within the year under report prior to June 15, 1935, was that which devastated Quetta, in Baluchistan, on May 30, 1935. Our recorded amplitudes for this shock are less than those for the Indian earthquake of January 15, 1934, and the distance is only slightly greater, so that the present shock is without doubt of lesser magnitude.

Application of the magnitude scale to our recorded shocks has led to the delimiting of an area within which we can expect to register and locate all shocks of magnitude 3 or more. This includes all the shocks likely to be reported felt, except under especially favorable circumstances. The area includes most of Southern California, and immediately adjacent Mexico (north of 32° N. Lat.). During the calendar year 1934, the data are as follows:

Magnitude	Number of shocks
3	114
3.5	63
4	21
4.5	9
5	4
5.5	1
6	1
Total	<u>213</u>

Of these, only 20 could be aftershocks of the Long Beach group. Nearly all of the group of Mexican shocks discussed above occurred too far south to be included in this statistical summary. The shock of magnitude 6 is the Parkfield shock of June 7, 1934.

Careful application of the magnitude scale to shocks of recent years have made it possible to construct an unobjectionable list of the recent large shocks of the region. The following list includes all shocks of magnitude 6 and over, beginning with 1932:

1. June 6, 1932	Off Eureka	6.1
2. December 20, 1932	Nevada	7.5
3. March 10, 1933	Long Beach	6.2
4. June 25, 1933	Nevada	6.2
5. January 30, 1934	Nevada	6.5
6. March 12, 1934	Utah	7.0
7. June 7, 1934	Parkfield	6.0
8. July 6, 1934	Off Oregon	6.0
9. December 30, 1934	Mexico	6.2
10. December 31, 1934	Mexico	6.5
11. February 23, 1935	Mexico	6.0

It may be noted with emphasis that four of these were greater than the Long Beach earthquake. This includes only the nearer shocks. If the distance limit were extended somewhat, a number of large shocks in the Gulf of California and off the west coast of Mexico should be included, but magnitude determinations for these shocks are at present not reliable. The time limit could be extended back to the date of the Point Arguello shock of November 4, 1927, without adding any further shocks of this magnitude in the region considered—unless it were desired to include the shock of October 1, 1931, which occurred in Lower California at about 30° N. Lat., with a magnitude of about 6.2.

The excellent quality of the recordings at Pasadena has made it possible to use data referring to most of the larger shocks of the past four years. The seismograms from the field station of the Department of Terrestrial Magnetism of the Carnegie Institution in Huancayo, Peru, which are now filed at the Seismological Laboratory, have proved of the greatest value in this work. The results are chiefly technical, having to do with the propagation of seismic waves in the interior of the earth, but one new result is of geological importance. On the evidence of the velocities of surface waves, it has been known for some time that the crustal structure of the continents, and that of the bed of the Atlantic Ocean, differ from that of the Pacific basin—the cause being very probably the absence of the continental or granitic layer from the Pacific region. It is now found that, especially at certain distances, the intensity of the reflected longitudinal wave, PP, is much affected by the structure at the point of reflection; so that it becomes possible to distinguish between continental and Pacific structure at those points which lie midway between epicenter and station. At Pasadena, Pacific type reflections are received as a general rule, conspicuous exceptions being provided by such shocks as the Baffin Bay earthquake of 1933, where the reflection takes place within the North American continent. As expected, it is found that reflections at points in the Atlantic Ocean are of the continental type; the same applies to the Indian Ocean. However, reflections taking place near the north pole are of the Pacific type, indicating that the continental layer is absent from the Arctic basin.

DEVELOPMENT OF INSTRUMENTS¹

Work on the improvement of instruments previously developed and the design and development of new apparatus has been carried on, in part, with the aid of men employed by the U. S. Coast and Geodetic Survey in connection with the strong-motion earthquake research program of the Survey (p. 360). This cooperative work has required more time than was anticipated, but the instruments developed in this connection will be of service later on.

The horizontal component electromagnetic seismometer described in earlier reports has been improved by the substitution of the new type push-pull transducer (also described in an earlier report) for the older form. The instrument is damped electromagnetically by the reaction of the output cur-

¹ Dr. Hugo Benioff.

rents. The constants can be adjusted to equality with those of the vertical component seismometer.

The new instrument follows the general constructional characteristics of the older model. However, the inertia reactor has been divided at the middle to permit mounting the new transducer symmetrically between the halves. A device for the determination of constants has been added. In effect this consists of a small platform supported on a set of steel ribbons in such a way that a small weight dropped on the platform exerts a horizontal force on the pendulum equal to the weight. Thus, in practice, the method of determination of constants is identical with that worked out for the vertical component seismograph.

Two horizontal component instruments of this type have recently been set up at the Harvard University seismographic station as companions to the vertical component seismograph already in operation there. It is believed that this assembly represents the first three-component seismograph of high magnification in which all components have exactly equal constants. A report indicates that observations of a recent blast made with this assembly permitted determination of the azimuth directly without reduction to ground displacement, with an accuracy of ± 1 degree..

Following news of an instrument which was being designed in Jena, a preliminary experimental model of a visible-writing system for seismographic recording has been designed. The instrument is operated from the long-period galvanometer of the vertical electromagnetic seismograph. Light from the galvanometer mirror falls on a photo-electric cell in such a way that the output currents are proportional to the galvanometer deflection. The currents are amplified and then recorded by a large ink-writing galvanometer. In the preliminary form the instrument is not wholly satisfactory for routine operation, partly because it required a group of storage batteries of very constant potential. In the revised form the instrument operates successfully from the 110-volt alternating current line as power source. The instrument uses a push-pull system throughout, beginning with two photo cells and ending with two galvanometer windings. The pen galvanometer has a period of approximately 0.25 sec. For seismic periods of 1 second and longer the response is substantially identical with the photographically recording instrument.

PORTABLE SEISMOGRAPH ASSEMBLY

The design and construction of a new form of electromagnetic seismograph is being carried on in cooperation with the California program of the U. S. Coast and Geodetic Survey (p. 360).

The assembly consists of four portable electromagnetic seismometers arranged with galvanometers to record simultaneously on a single moving film. It is hoped that with such an instrument observations can be made on the simultaneous movements of the various floors and parts of buildings during aftershocks. A further use, not contemplated at first, is the simultaneous recording of ground movements at four points separated by distances up to several kilometers. Such an arrangement will operate like a geophysical

seismographic outfit and can be used for the determination of the direction of propagation of seismic waves in earthquakes, or in microseisms, and for other local earthquake problems.

The four-component galvanometer and two of the seismometers have been completed to date. The seismometers are of the general type designed for routine operation, but are changed considerably in detail. They are completely enclosed in a weather-proof aluminum housing and weigh approximately 50 pounds each. The inertia-reactor is made up of the moving elements of the transducer only and is suspended by four heavy phosphor-bronze ribbons. The period is normally adjusted to 1.5 seconds. It can be varied over a range of approximately 0.5 second by means of an auxiliary tension member. The damping force is derived from the reaction of the output currents and is adjusted to a value $h = \frac{1}{2} \sqrt{2}$. The galvanometer assembly is made up of four independent units. The period of each element is 1.5 secs., and the damping constant is $h = 20$. The galvanometers thus behave as fluxmeters, so that over the period range, $\frac{1}{10}$ to 4 seconds, the response of the seismograph is substantially that of the pendulum units. For the projected problem, therefore, the assembly provides the characteristics of ordinary pendulum seismographs with the flexibility and advantages of electromagnetic instruments. The magnification is adjustable over a range from 30,000 to 100 approximately.

Further work by the methods of geophysical prospecting has been conducted under the auspices of the California Institute of Technology. Dr. Buwalda and Dr. Gutenberg, aided by students of the Institute, did work of this kind in the Wyoming region and in Yosemite Valley with aid from the Geological Society of America, and work on Frazier Mountain and in the Los Angeles basin with funds obtained from local sources.

Under the direction of Dr. Gutenberg, a detailed investigation has been made by men working for the U. S. Coast and Geodetic Survey of the prevailing periods recorded on the seismograms of shocks in this region registered at our several stations. The results found are very consistent and will be published by the U. S. Coast and Geodetic Survey.

PUBLICATIONS

At a meeting of the Seismological Society of America held on April 12 and 13 in conjunction with the meeting of the Cordilleran Section of the Geological Society of America, at Stanford University, Dr. Richter presented a paper entitled "Further Results with the Magnitude Scale." Dr. Benioff presented a paper entitled "Instrumental Method for the Determination of the Extent of Faulting." The following two papers were presented by Dr. Richter and Dr. Gutenberg jointly: "Observed P at about 20 Degrees and the Question of Sub-crustal Discontinuities;" "Effect of Crustal Structure on the Reflection of PP."

An important publication, in the preparation of which the Seismological Laboratory has had a considerable share, is the list of "Destructive and

Near-destructive Earthquakes in California and Western Nevada, 1769-1933, by Harry O. Wood, Maxwell W. Allen, and N. H. Heck," issued as Special Publication No. 191 of the U. S. Department of Commerce, Coast and Geodetic Survey (1934). Extended and repeated careful discussion has gone into the preparation of this list, and while numerous imperfections are known to exist, with others undoubtedly not yet brought to light, it is the most satisfactory document for its special purpose now in print. A generous share of credit belongs to Dr. Richter, whose name does not appear, for collaboration in this compilation.

Besides these, the following papers have been published. The first publication on this list should have been included in the report for last year, 1933-1934, but was inadvertently omitted.

PUBLISHED PAPERS

1. Chapters by Harry O. Wood, as given below, in *Physics of the Earth—VI, Seismology*. Bull. Nat. Res. Council, No. 90, October, 1933.

<i>Chapter</i>	<i>Pages</i>	<i>Title</i>
3	9-31	Volcanic Earthquakes
6	41-66	Earthquake Investigation in the Field
7	67-82	"Apparent" Intensity and Surface Geology

2. *Seismological Research in Southern California*, by Harry O. Wood. Proc. Fifth Pacific Science Congress, vol. III, 2347-2353, 1934.
3. *A New Electro-Magnetic Seismograph*, by Hugo Benioff. Proc. Fifth Pacific Science Congress, vol. III, 2443-2450, 1934.
4. *On Seismic Waves, First Paper*, by B. Gutenberg and C. F. Richter. *Gerlands Beitr. z. Geoph.*, vol. 43, 56-133, 1934.
5. *The Physical Evaluation of Seismic Destructiveness*, by Hugo Benioff. *Bull. Seis. Soc. Amer.*, vol. 24, No. 4, 398-403, October 1934.
6. *A Seismographic Recorder*, by Halley Wolfe. *R. S. I.*, vol. V, 359-361, October 1934.
7. *An Instrumental Earthquake Magnitude Scale*, by Charles F. Richter. *Bull. Seis. Soc. Amer.*, vol. 25, No. 1, 1-32, January 1935.
8. *Earthquakes in California*, by Harry O. Wood. *Scientific Monthly*, vol. XXXIX, No. 4, 323-344, October 1934. Also issued as: *Earthquake Study in Southern California*, Carnegie Inst. Wash., Suppl. Pubs. No. 12, February 15, 1935.

For the sake of completeness the following three titles are included though not strictly pertaining to activities proper to this report.

9. *Crustal Deformations of Gradual Type*, by Beno Gutenberg. Proc. Fifth Pacific Science Congress, vol. III, 1297-1304, 1934.
10. *The Structure of the Earth's Crust as Indicated by Seismological Data*, by Beno Gutenberg. Proc. Fifth Pacific Science Congress, vol. III, 2511-2521, 1934.

11. Investigation of Overthrust Faults by Seismic Methods, by John P. Buwalda and Beno Gutenberg. *Science*, vol. 81, No. 2103, 384-386, April 19, 1935.

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Advisory Committee in Seismology.

DIVISION OF PUBLICATIONS¹

FRANK F. BUNKER, EDITOR

In the report of the Division of Publications for the year ending October 31, 1934, published in Year Book No. 33, a general outline was given of the publishing practise which has developed in the Carnegie Institution in response to the needs of an organization created for the purpose of prosecuting fundamental research.

A REVIEW

In this sketch it was stated that until within a few years the publishing activities of the Institution were limited to issuance of the Year Book and of monographic reports on the progress of research, and to assisting the technical journals of certain fields in publication of special articles prepared by the Institution staff. It was also stated that when the administrative responsibility for the Institution passed to Dr. John C. Merriam study was undertaken as to how the Institution, while maintaining its established program, could increase its opportunities for service through disseminating interpretations of research results among non-specialized persons as well as among scientists generally.

It was mentioned that out of this study emerged the *News Service Bulletin*, sent to the foreign and domestic press and to a selected list of schools; the *Supplementary Publications Series*, comprising, for the most part, lectures by members of the staff, given under Institution auspices; and the *Clip Sheet Service*, which consists of the issuance of short, simply written statements about significant phases of the investigational work of the Institution, suitable for use of the press.

The method developed by the Institution for distribution of its Year Books and the monographic publications which it issues was also described, as was the history of the relation of the Institution to the publication known as the *Index Medicus*. Mention was also made of the assistance in distributing the Institution's publications rendered by the United States International Exchange Service which operates under Congressional appropriation, administered by the Smithsonian Institution.

THE PROBLEM OF PAPER PERMANENCE

At the commencement of the publishing activities of the Institution, thirty-three years ago, question arose as to provision for the permanence of the Institution's publications. In the light of all that was then known about the agencies affecting the life of paper, decision was reached that papers made of rags of the best grade gave the greatest promise of durability. Accordingly, in order to be assured of obtaining paper of acceptable quality, arrangements were made with paper mills to manufacture special lots, as needed, expressly for Institution use. This plan still prevails and today,

¹ Address: Carnegie Institution of Washington, Washington, D. C.

as in the beginning, the more important books of the Institution are printed on all-rag stock, manufactured for the Institution in accordance with specifications which have been modified from time to time as experience and special needs have prompted.

In the more recent years the assumption that all-rag papers are more suitable for scientific publications than other papers has been challenged. For this reason and because of mounting costs of printing, investigation of the matter was again undertaken.

REPORT OF THE WAVERLY PRESS

Statement of the case was competently made by Mr. William M. Passano of the Waverly Press, Baltimore, who had conducted a study of the matter for his firm. In the report which he was invited to submit to the Division of Publications, Mr. Passano said:

"During the past several years we have made rather extensive investigations as to the most suitable papers to use in scientific publications. These investigations have consisted of talking with chemists of some dozen paper mills, and then with all this information before us of deciding what in our minds were the correct papers.

"The papers to use in scientific work must before all else be permanent and not subject to discoloration and deterioration. Deterioration in paper is caused by the fact that the chemicals used in bleaching the wood pulp in making paper are not entirely removed and set up reactions with the atmosphere. Also, destructive foreign matter can be added to the paper in the making. This can come from several sources, such as iron pipes for carrying the mill's water supply, an impure water supply, etc. First, then, it is essential that a mill making paper which is to have a high degree of permanency must use copper pipe throughout, and have a very pure water supply. Secondly, it is essential that chemicals used in bleaching the pulp be removed as far as possible.

"Pulp for paper making is obtained from many substances. Wood, rags, corn stalks, esparto grass are among the more common. All are cellulose and the purer the cellulose the more permanent the paper. Pure cellulose may be obtained from rags with less drastic treatment than from any other source, so it follows that rag pulp is logically used where it is essential that paper will not deteriorate over a long period of time.

"The average run of commercial rags used in book paper are cotton rags which have been dyed and which are dirty. It is as hard to remove the chemicals from such rags as it is to remove the chemicals used in bleaching wood pulp; and so, as far as we can see, the only advantage of using commercial rags in making book paper is to obtain slightly greater strength, since the cotton fibers are stronger than the wood fibers.

"In the very highest grades of paper, linen rags, known as shirt clippings, are used. These are perfectly clean, have never been dyed, and, consequently, are chemically pure. Also the flax fiber is stronger than either the cotton or the wood. The cost of these rags is such that their use is prohibitive in book papers. We have seen sheets of paper which have no rag content, and which are over thirty years old, that are just as strong as a similar paper made today, and that have not shown any discoloration.

However, no one has ever claimed that paper without a rag content lasts longer than paper made partly of rags.

"We do feel that rag in a paper does give it a certain feel and finish which is impossible to obtain without it. Consequently, we have played safe, and specify in our papers one-third rag and two-thirds soda and sulphite pulp. These papers we are sure will last one-hundred years without deterioration. It seems economically wrong to tax scientific publications with the expense of using 100 per cent rag content when cheaper paper would last such a long time."

COMMENT OF THE BUREAU OF STANDARDS

This report was submitted for comment to the National Bureau of Standards. The observations of the Bureau follow:

"We agree in most respects with Mr. Passano's report. If second-grade rags are used, it is doubtful if the paper will have much better permanency than the best grades of papers made from wood fiber. We believe that such grades of rags are usually used for making the ordinary grades of rag printing papers. If very great permanency is desired, it is necessary that the best grades of rags be used, but of course the cost of such papers is high.

"Judging from past experience, it seems rather doubtful if wood fiber papers have quite the permanency mentioned by Mr. Passano. We are inclined to believe their permanency would be considerably less, although it is impossible to make a definite statement in this respect.

"Unless the very highest grade of rag paper can be used it would seem to us advisable to use one of the highest grades of wood fiber printing paper, as such papers no doubt will have fair permanency and possibly will answer your purpose."

Accompanying the foregoing remarks was a further statement from the Bureau of Standards. Since it throws additional light upon the problem it is quoted herewith:

"The degree of permanence of paper is a matter of vital importance. Little is known definitely of the permanence of modern papers and the numerous requests received by the Bureau of Standards, from the Federal Government departments and from State Governments, from the Library of Congress, and public libraries, and from many business concerns, for advice respecting durability of papers, indicate that the importance of this property of paper is generally realized. The Bureau has made some research on this subject, but has not been able to make the intensive study required to obtain definite information on the many different questions involved. In view of the numerous demands for information, however, the following observations may be of interest:

"From records of the aging of papers, it appears that wood fiber papers in general have given poor service in respect to permanence. Rag fiber papers in general have alone proved suitable for permanent records. But the fact that a paper is made entirely of rag fiber does not in itself ensure permanence. The materials entering into the paper must be chosen with care so that no materials will be present which are in themselves unpermanant or which will induce deterioration of the paper. It is quite well

established that for fibers in themselves to be permanent, they must be reduced to as pure form of cellulose as possible. The purity of the fibers is commonly measured by determining the copper number.

"As rosin sizing induces decomposition of paper fibers, it should not be used. Judging from past records and from results of accelerated aging tests, the sizing should consist of glue only, as when properly applied such sizing is very permanent and has no injurious effect upon the paper fiber. Starch sizing appears to be of doubtful permanence. Chemical residues, especially those of an acid nature, are very harmful. Alum is an acid salt commonly used in paper sizing and care must be taken that residues of this material in the paper are kept at a minimum. Other chemical residues such as those derived from cooking and bleaching operations should also be reduced to a minimum. In employing coloring materials, only those of established permanency should be used, and only those which will not react chemically with other constituents of the paper."

FURTHER INVESTIGATIONS BY THE BUREAU

Still more recently, as a result of continuing investigations of paper permanency, the Bureau of Standards has modified somewhat its position relative to the superiority of rag-fiber papers.

Mr. B. W. Scribner, Chief of the Paper Section of the Bureau, says that during the past few years there has been considerable improvement in the methods of producing highly refined wood fibers and that in consequence "both wood fibers and rag fibers now appear to be satisfactory for permanent record use." Mr. Scribner's complete statement made under date of October 14, 1935, follows:

"Through a review of the information available, including both laboratory studies and the history of the natural aging of papers, it is shown that the processing of the fibers and the care taken in the various papermaking operations are the important factors in determining how well papers will withstand deterioration. The strength of paper and its purity are dependent on these factors.

"Papers must have sufficient strength to withstand the mechanical stresses incident to their use and must have sufficient purity, both cellulosic and non-cellulosic, to guard against chemical reactions that induce decomposition. The basic constituent of paper fibers is cellulose, which is one of the most permanent forms of matter known. Cellulose is very susceptible, however, to deterioration induced by impurities that may be associated with it and by some of the chemicals that are used in paper manufacture.

"From these considerations a classification based primarily on strength and purity is suggested, which places printing and writing papers in four groups: (1) permanent papers, (2) papers having a minimum life of 100 years, (3) papers having a minimum life of 50 years, (4) papers for temporary use.

"It is suggested that the various grades for all except the papers intended for temporary use be defined by limits for alpha cellulose, copper number, rosin, and acidity, as all of these properties appear to have an important bearing on aging quality. A high content of alpha cellulose and a low copper number are considered the best known indications that the paper fibers have the basic purity required for long life. Minimum amounts of rosin

and acid are desirable as those components are harmful to any fiber, no matter how pure it may be, if they are present in excessive amounts.

"A suggested classification and detailed specification of this kind for both writing papers and book papers has been prepared by the Bureau. Extensive tests of the various grades of rag- and wood-fiber papers, including both accelerated aging and natural aging, have shown that fibers from both of these sources are suitable for permanent-record use."

BUREAU OF STANDARDS SPECIFICATIONS

The tests for durability referred to consist of analyzing the paper for copper number, alpha cellulose, content acidity, and folding strength, then, after keeping the paper in an air oven for 72 hours at 100° Centigrade, noting the change in the four factors listed above. Their change as well as their absolute value form an index to the permanency of the paper being tested. Out of these tests has come formulation by the Bureau of specifications for each of the four grades of paper stock mentioned above. These follow:

"Grade I. Permanent papers, having a maximum degree of purity; free from unbleached fibers, and highly lignified fibers such as ground wood. Indicative chemical properties: Alpha cellulose, 90 per cent; copper number, 1.5; rosin, 1 per cent; acidity, 5 pH. Changes on heating 72 hours at 100 degrees centigrade; decrease in content of alpha cellulose should be not more than 1.5 per cent; decrease in folding endurance not more than 25 per cent; increase in copper number not more than 0.5.

"Grade II. Papers quite highly purified that may be expected to have a minimum life of 100 years; free from unbleached fibers, and highly lignified fibers such as ground wood. Indicative chemical properties: Alpha cellulose, 80 per cent; copper number 2.5; rosin, 1.5 per cent; acidity, 5 pH.

"Grade III. Papers having a fair degree of purity that may be expected to have a minimum life of 50 years; free from unbleached fibers, and highly lignified fibers such as ground wood. Indicative chemical properties: Alpha cellulose, 70 per cent; copper number, 5; rosin, 2 per cent; acidity, 5 pH.

"Grade IV. Papers having a low degree of purity containing considerable organic impurities, suitable for current use only. This grade includes papers containing unbleached fibers, and highly lignified fibers such as ground wood.

"All figures given for chemical components in these grade descriptions are upper limits, except for alpha cellulose contents which are lower limits. Alpha cellulose content and copper number are based on total cellulose content."

THE POSITION TAKEN BY THE GOVERNMENT PRINTING OFFICE

The preliminary draft of this discussion was submitted for comment to Mr. M. S. Kantrowitz, Technical Director of the Government Printing Office, who states in response that the experience of the Government Printing Office indicates that rag content paper will prove more permanent than

chemical wood paper. Definite proof, he suggests, as to the permanence of paper made from fibers other than good quality of cotton, linen or hemp must await actual aging tests over a considerable period of time.

Mr. Kantrowitz expresses doubt as to the value of accelerated aging tests and states that the Government Printing Office does not include such a test in its paper specifications. On this point he quotes from the 1933 report of the Committee on Permanence and Durability of Paper which was made to the Research and Development Division of the Technical Association of the Pulp and Paper Industry. The excerpt from this report follows:

"The Committee believes that the various accelerated aging tests, employed for determining the probable life of a paper, at the present time, have not been confirmed by natural aging tests. The use of accelerated aging tests in specifications for paper are of questionable value, therefore, at the present time. Time has proven that permanence is insured by the use of new white or unbleached cotton, flax or hemp fibers, carefully processed, in the manufacture of a paper which is stored under average conditions."

In further comment upon factors which bear upon the problem Mr. Kantrowitz says:

"The permanence of paper does not depend upon quality alone; storage conditions must also be considered. Paper should be stored under normal atmospheric conditions. It is a well known fact that disintegration is greatly intensified when paper is stored in atmospheres rendered acidic by the presence of sulphur dioxide. It is also known that cellulose fibers are converted to oxycellulose or to hemicellulose under the prolonged action of actinic light or abnormally high temperatures. It is recommended that permanent records be stored under controlled atmospheric conditions of 50 per cent relative humidity and 70°-75°F. temperature."

CONCLUSION

Apparently all investigators are agreed that there is little doubt as to the satisfactory behavior of rag stock of good quality. Certain it is that the first of the Institution's publications, now upwards of thirty years old, give no visible evidence of deterioration.

The difference of opinion that has arisen relates rather to question whether paper from chemically treated wood fiber offers as great probability. The investigations so far made appear not to be sufficiently conclusive to justify the Institution, at this time at least, in receding from its original position.

STATISTICS OF PUBLICATIONS

The table which follows gives the Institution's yearly production of monographic publications now totaling 674 volumes, comprising 198,975 pages of printed matter.

Production of Monographic Publications

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902....	3	46	.....	46
1903....	3	1,667	.....	1,667
1904....	11	2,843	34	2,877
1905....	21	3,783	1,445	5,228
1906....	19	3,166	1,288	4,454
1907....	38	6,284	3,428	9,712
1908....	28	4,843	2,485	7,328
1909....	19	3,695	1,212	4,907
1910....	20	3,274	4,831	8,105
1911....	30	5,062	1,670	6,732
1912....	23	3,981	2,044	6,025
1913....	20	6,605	2,752	9,357
1914....	23	4,978	1,934	6,912
1915....	23	4,686	1,466	6,152
1916....	35	9,478	2,430	11,908
1917....	21	4,464	2,691	7,155
1918....	17	3,073	1,120	4,193
1919....	20	5,834	2,431	8,265
1920....	23	3,962	3,710	7,672
1921....	18	4,068	1,308	5,466
1922....	24	4,566	2,039	6,605
1923....	20	6,459	604	7,063
1924....	17	4,665	834	5,499
1925....	24	3,970	1,377	5,247
1926....	14	4,552	850	5,402
1927....	17	4,520	2,089	6,609
1928....	15	4,405	1,044	5,539
1929....	12	4,938	452	5,390
1930....	15	4,096	844	4,940
1931....	14	4,017	1,343	5,360
1932....	16	2,155	2,588	4,743
1933....	22	4,256	1,370	5,626
1934....	13	3,030	1,206	4,236
1935....	9	1,742	813	2,555
Total...	674	143,253	55,722	198,975

In addition, during the year, the Institution has issued the following: Nine numbers in its *Supplementary Publications Series*, comprising 12 articles, chiefly Institution lectures, totaling 411 printed pages, illustrated with many cuts; 13 numbers of the *News Service Bulletin*, totaling 106 printed pages and carrying 105 illustrations; and 13 numbers of the *Clip Sheet*, containing 44 short articles relating to the work of the Institution, suitable for use of the press.

Receipts from Sales of Publications

Year	Index Medicus	Year Book	Miscellaneous Books
1903.....	\$2,256.91	\$29 25	.....
1904.....	2,370.47	52 85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371 67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992 02	75.95	7,140.69
1914.....	5,079 16	49 65	6,273.59
1915.....	5,010 21	47 60	5,239.98
1916.....	4,382 19	46 60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324 29	21 10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50 55	10,356.84
1922.....	5,774 59	59 25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
1933.....	50.20	69.89	4,294.83
1934.....	81.60	50.31	4,500.51
1935.....	29.60	73.28	4,118.52
Total.....	111,670.70	2,095.53	206,527.07

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